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ALTERNATE T-38 TRANSPARENCY DEVELOPMENT
Part II: Baseline Birdstrike Testing

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Final Technical Report for Period June 1979 - October 1980

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T-38 missions at speeds above the existing crew enclosure damage threshold will result in flight safety risk to aircraft. This report documents the results of a full-scale flight hardware test program to establish the bird impact resistance of existing T-38 forward transparencies. The failure threshold for the forward windshield and forward canopy for a four-pound birdstrike at six impact locations was established. Test results are reported and discussed in detail.

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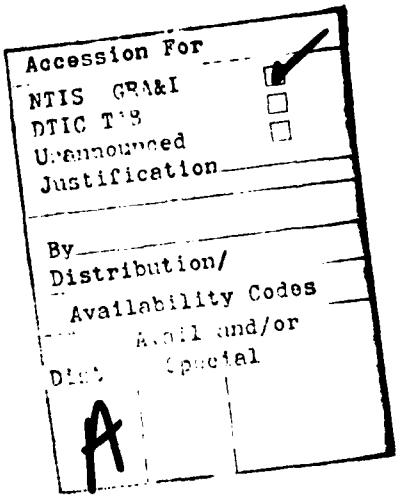
FOREWORD

The effort documented in this report was performed by the Applied Mechanics Group, Aerospace Mechanics Division of the University of Dayton Research Institute, Dayton, Ohio, under Contract F33615-76-C-3103, Project 2202, "Birdstrike Windshield Technology Program," and Contract F33615-80-C-3401, Project 1926, "Birdstrike Resistance Crew Enclosure Program," for the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. Air Force administrative direction and technical support was provided by Capt. Walter W. Saeger, Jr., AFWAL/FIEA, the Program Manager. Birdstrike testing was performed at Arnold Engineering Development Center, Arnold Air Force Station, Tennessee. On-site test direction was provided by Capt. Walter W. Saeger, Jr., AFWAL/FIEA and Mr. Blaine West, University of Dayton Research Institute.

The test program described herein was conducted during August 1979. Project supervision and technical assistance was provided through the Aerospace Mechanics Division of the University of Dayton Research Institute with Mr. Dale H. Whitford, Supervisor, and Mr. Blaine S. West, Head, Applied Mechanics Group and Project Engineer.

The active support and substantial contributions of Capt. Walter W. Saeger, Jr., AFWAL/FIEA to the success of this project is gratefully acknowledged. In addition, the author wishes to express appreciation to the Arnold Engineering Development Center test personnel for their cooperation and assistance to successfully complete the required work.



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SECTION 1
INTRODUCTION

The T-38 aircraft was originally designed to train Air Force pilots in the fundamentals of high speed aircraft flight at altitudes exceeding 10,000 feet above ground level. Recently, the mission usage has changed with the addition of low level navigation training flights as low as 1,500 feet above ground level at speeds approaching 400 knots. This has significantly increased the danger of sustaining birdstrikes on the aircraft since the bird population is concentrated below 10,000 feet.

This increased birdstrike potential caused concern within the using command, Air Training Command (ATC), over pilot safety and aircraft survivability. Originally, the T-38 transparency system was not designed to provide birdstrike protection since no specific birdstrike requirement existed and it was believed that aerodynamic flow would not allow damaging bird impacts with the transparencies. This assumption has proved wrong on numerous occasions; resulting in four aircraft being destroyed and three pilots killed (as the direct result of the transparency birdstrike) since the T-38 became operational in 1964. The birdstrike protection level of the forward windshield was increased in 1969 but it is now considered inadequate for mission requirements. The forward canopy impact resistance was not increased due to the ATC's desire to retain through-the-canopy (TTC) ejection as a back up means of escape.

The Vehicle Equipment Division Advanced Development Program Office of the Flight Dynamics Laboratory has instituted a program to develop improved forward facing transparencies for the T-38 (reference Figure 1). Originally the program was to address only the forward windshield and forward canopy but when ATC decided in November 1979 that it could not give up the back up TTC ejection capability, the instructor windshield was included in the development effort. This was done in recognition that development of a

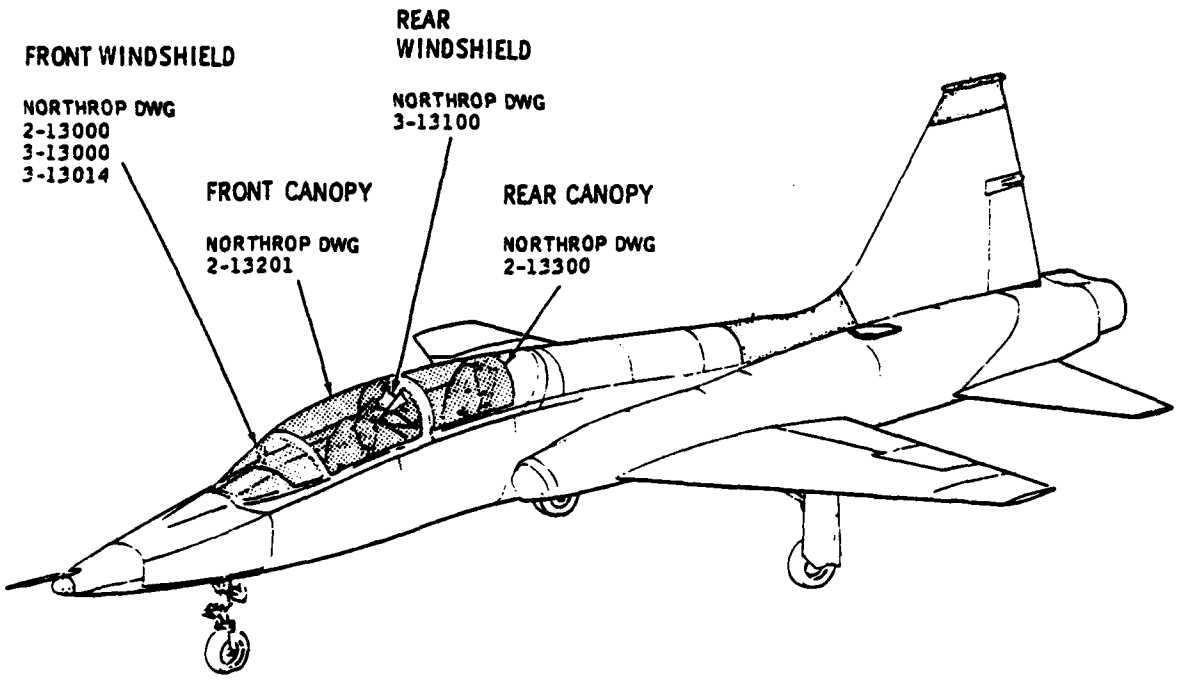


Figure 1. T-38 Crew Enclosure.

forward canopy that provides the desired four pound 400 knot birdstrike protection requirement while retaining TTC ejection capability will require integration of diverse technologies that may take significantly longer development times than the development of a canopy that satisfies only the birdstrike requirement. By including the instructor windshield for development of increased birdstrike protection, the current forward canopy can be continued in use while the instructor pilot, who sits in the aft cockpit, is provided adequate protection from birdstrikes that penetrate the forward canopy.

SECTION 2
BACKGROUND, OBJECTIVES, AND APPLICATION

2.1 BACKGROUND

During Northrop Corporation's development of the 0.600-inch forward windshield, birdstrike testing was conducted (Reference 1) on the windshield but limited to an impact point at the vertical/horizontal centerline of the windshield and parallel to the aircraft centerline. Although this gave the windshield centerline birdstrike capability there was some question as to the adequacy of the edge attachment design should a birdstrike occur off-center so as to involve the transparency edge attachments.

Transparency/support systems of similar design have shown reduced capability (Reference 2) in the area where the transparency is constrained by supporting structure and load transfer through the transparency edge member becomes significantly higher. This potential for reduced capability provided the impetus for conducting the testing program described in this report.

2.2 OBJECTIVE

The primary objective of this birdstrike test program conducted in August 1979 was to determine the baseline birdstrike protection level as a function of birdstrike location for the current production forward windshield and forward canopy in use on the T-38 fleet. The forward windshield is currently 0.600-inch monolithic stretched acrylic while the forward canopy is 0.230-inch monolithic stretched acrylic. All test articles were to be

(1) W. G. Shirreffs, "T-38 Bird Impact Resistivity Tests," NOR-68-121, August 1968.

(2) Blaine S. West, "Design and Testing of F-111 Bird Resistant Windshield/Support Structure, Volume I - Design and Verification Testing," AFFDL-TR-76-101, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, October 1976.

mounted in current production framework and subjected to bird impacts with nominal four pound birds at predetermined impact velocities and impact locations. These results were to be utilized to establish the baseline birdstrike protection level.

2.3 PROGRAM APPLICATIONS

The baseline capability derived from the testing will be used for two purposes: (1) provide design/redesign inputs to the T-38 birdstrike resistant transparency development program, and (2) provide data for use in the birdstrike risk assessment model developed for use by the Air Force. In the first case, the capability of the forward windshield and forward canopy edge attachments and support structure to withstand bird impacts without failure was unknown. By testing this capability early, it would be determined that there is a need for immediate redesign or that the edge attachments and support structure can withstand impact energy levels in excess of the current transparencies. If the latter situation occurs, the ability to withstand the energy levels associated with higher impact velocities cannot be tested until higher capability transparencies are developed.

The birdstrike probability model (Reference 3) provides the ability to predict the probability of sustaining a birdstrike of a given energy level which can then be used to predict the probability of the birdstrike being damaging if the impact energy capability of the aircraft transparency system is known.

Risk assessment studies using the birdstrike probability model have been conducted using estimated values for the critical impact energy level of the T-38 forward transparencies. This test program will confirm the accuracy of those estimates or provide corrected data for use in the prediction model.

(3) A. P. Berens, B. S. West, and M. A. Turella, "On a Probabilistic Model for Evaluating the Birdstrike Threat to Aircraft Crew Enclosure," UDR-TR-78-124, University of Dayton Research Institute, Dayton, Ohio, November 1978.

SECTION 3
EXPERIMENTAL PROCEDURE

The basic procedure in bird impact testing at Range S-3 of the von Karman Gas Dynamics Facility, Arnold Engineering Development Center (AEDC) consists of launching bird carcasses at specified velocities (using the air-driven launcher) into predetermined impact locations on a test article placed into the flight path of the bird. For the current test, six impact locations on the T-38 forward transparencies were investigated. All tests at impact points along the fuselage centerline were conducted with the fuselage oriented at 0° pitch - 0° yaw attitude relative to the launch path. Transparency side tests at two locations were made with the module yawed 15° clockwise. From two to five tests on each transparency were required to determine the ballistic limit at each impact location.

3.1 TEST FIXTURE

Previous birdstrike testing on the F-111 and other aircraft revealed that the most realistic response of the transparency and its support structure was achieved if at least part of the aircraft fuselage to which the transparency was attached could be simulated as part of the birdstrike test fixture. To achieve this at the lowest fabrication cost, it was desirable to use the forward fuselage section from a nonflyable T-38 if one could be obtained. An F-5/T-38 forward fuselage section that was mounted on a rocket-powered sled for use in ejection seat testing was available from Northrop Corporation, Hawthorne, California. As Government equipment being stored at Northrop under an existing F-5 contract, permission for its use was obtained from the ASD Fighter/Attack SPO and the contract ACO at Northrop AFPRO.

The fuselage section was shipped to Arnold Engineering and Development Center (AEDC), Tullahoma, Tennessee, mounted on the test sled to reduce the possibility of damage to the fuselage. Once it arrived at AEDC, the fuselage section was unbolted and

removed from the sled base and mounted on the moveable table in the S-3 range of the von Karman facility (see Figures 2 and 3). The moveable table is used to position the test article as necessary for the desired impact location. The table allows for ±20 inches vertical and ±16 inches horizontal movement. The compressed air launch tube is fixed, not allowing movement for adjustment purposes.

A forward windshield and forward canopy representative of current production models were mounted on the fuselage in preparation for testing. The instructor windshield (rear windshield in Figure 1), which came with the fuselage section, had been badly charred in previous ejection seat testing and was replaced to allow mounting of a high speed camera in the aft cockpit to record the birdstrike event from the inside. Since the instructor windshield is a nominal 0.460 inch stretched acrylic flat plat, a 0.50-inch-thick piece of plexiglass was cut to shape and mounted immediately in front of the instructor windshield to provide additional protection for the camera. This was subsequently replaced after shot number 640 with a 1-inch-thick piece of plexiglass when bird remains caused the 0.50-inch piece of plexiglass to flex and impact the instructor's windshield, cracking the instructor's windshield and requiring it to be replaced.

3.2 TEST ARTICLES

The items to be tested were representative of production forward windshields and forward canopies currently installed on active Air Force inventory T-38's. The forward windshields were obtained through Air Force supply channels from aircraft in storage at Davis-Monthan Air Force Base, Arizona, and Swedlow, Incorporated, Garden Grove, California. The forward canopies were obtained from Davis-Monthan Air Force Base, Arizona, and from San Antonio Air Logistics Center, Kelly Air Force Base, Texas. Removal and use of transparencies and frames from T-38's at Davis-Monthan was required by a shortage of spare parts within

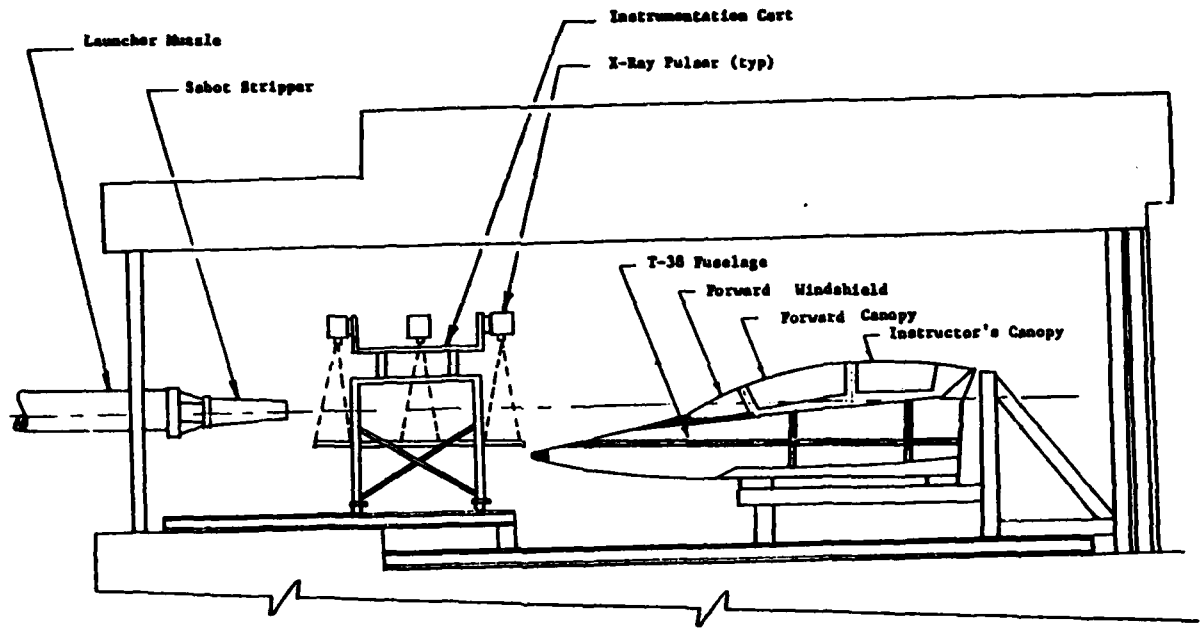


Figure 2. Arnold Engineering Development Center Test Area Arrangement.

Figure 3. Test Module Installed at Arnold Engineering Development Center Test Facility.

the Air Force supply system. It was felt that any difference in the test results between virgin and previously flown transparencies would be minimal and have little effect on the resulting data. The transparencies obtained from Davis-Monthan were received mounted in their frames to shorten installation time prior to the first test. After a transparency had been broken, it was removed from the frame, the frame was examined to ensure that no structural damage had occurred that would prevent its reuse, and a new transparency was then mounted in the frame in preparation for further testing.

3.3 PROJECTILES AND SABOTS

Projectiles used during the test program were nominally four-pound chicken carcasses. The birds were asphyxiated, placed inside a polyethylene bag, quick-frozen, and stored at 0°F until needed. Prior to testing, the carcass was thawed in still air at room temperature (75°F) for approximately 24 hours, or until the body cavity temperature was approximately 60°F. Adjustments to the bird carcass weights were required at times to satisfy the 4.0 ±0.1 pound weight requirement. These adjustments were accomplished by clipping carcass appendages or injecting water into the body cavity. In no case did the weight adjustment exceed 0.4 pound (10 percent of projectile weight).

The bird was prepackaged in a polyethylene bag to help it maintain its shape while traveling through the air prior to impact. The packaged bird was mated to the launch tube using a one-piece sabot of balsa-wood construction. The sabot material density was a nominal 10 lb/ft^3 providing a sabot weight of 1.7 lbs and a total launch weight of 5.7 lbs. The packaged bird and sabot were launched using the compressied air launch tube at the S-3 range. Separation of the bird and sabot after launch was accomplished with the use of the tapered and threaded cylindrical sabot stripping section attached directly to the vent section of the launch tube. As the launch package entered the stripper section, the sabot velocity was gradually brought to rest permitting the bird to exit the sabot and continue on to the target in free-flight.

A number of calibration shots without the test fixture (forward fuselage section) in place were conducted prior to the initiation of the test series. The calibration shots were required since the velocities to be used initially in the T-38 program were lower than those of any previous test program. Good repeatability was obtained and calibration charts for both projectile velocity and vertical drop due to gravity as a function of air pressure were formulated by personnel at AEDC for use in the actual test phase.

3.4 INSTRUMENTATION

High Speed Movie Cameras

Four high speed movie cameras (4,000 frames/sec) were utilized to provide a photographic record of each shot. The cameras were positioned as shown in Figure 4 except for slight adjustment to allow focusing in on the forward windshield or forward canopy at a specific impact location. The cameras were positioned to obtain coverage of the impact location and failure modes, transparency edge attachment reactions, and transparency-support structure interactions. Since the total impact-failure sequence occurs in milliseconds, high speed film provides a means to visually examine the events as they took place. In general, the films were available within 24 hours and were received prior to finalizing the velocity for the next shot. This was done to allow the on-site Flight Dynamics Laboratory test director to take into consideration potential failure modes or problems exhibited in the previous test and to adjust the impact velocity as required.

Still Photographs

In addition to high speed movies, still color photographs were taken before and after each shot to record damage or other visual evidence which would aid in interpreting and documenting the test results.

Strain Gages

Strain measurements were made using Micromeasurements CEA-13-125UW-120 (uniaxial) and CEA-13-125UR-120 (rosette) gages

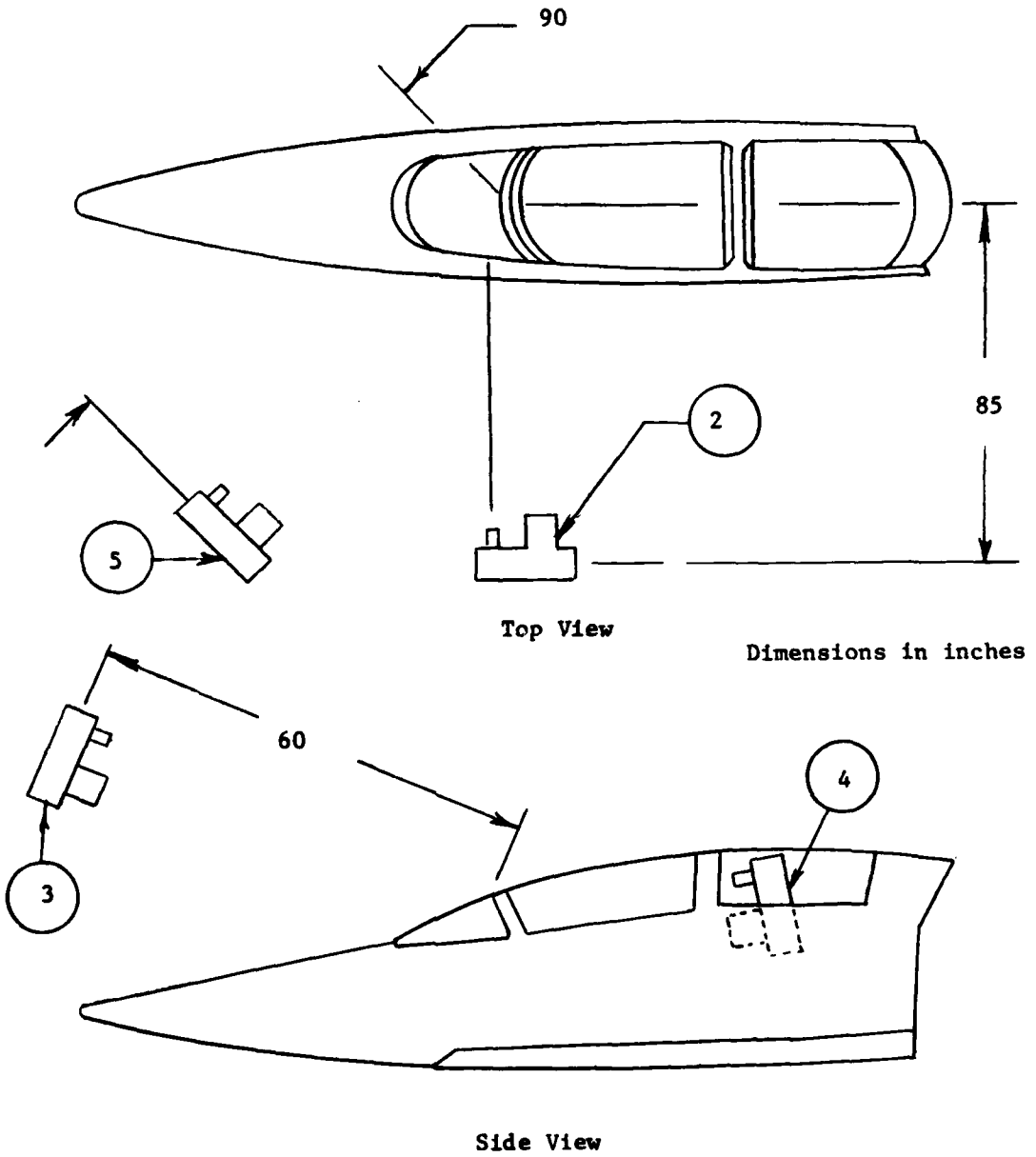


Figure 4. Nominal Motion Picture Camera Positions.

positioned at locations 1L, 2L, 3L, 1R, 2R, and 3R on the aft member of the forward windshield frame as shown in Figure 5. The gages were bonded to the frame's lower surface using Micromeasurement's AE-10 adhesive and coated with Micromeasurement's M-Bond B as a moisture seal. Each gage was additionally protected with an overcoat of RTV 732.

Strain gage dynamic response was monitored and recorded by a data acquisition system comprised of recording oscillographs and magnetic tape machines. Modular bridge completion networks and amplifiers supplied the strain signals. Overall system bandwidth was dc to 80 kHz. System calibration was accomplished using resistances, paralleling active strain gages, producing bridge unbalance signals corresponding to known strain levels.

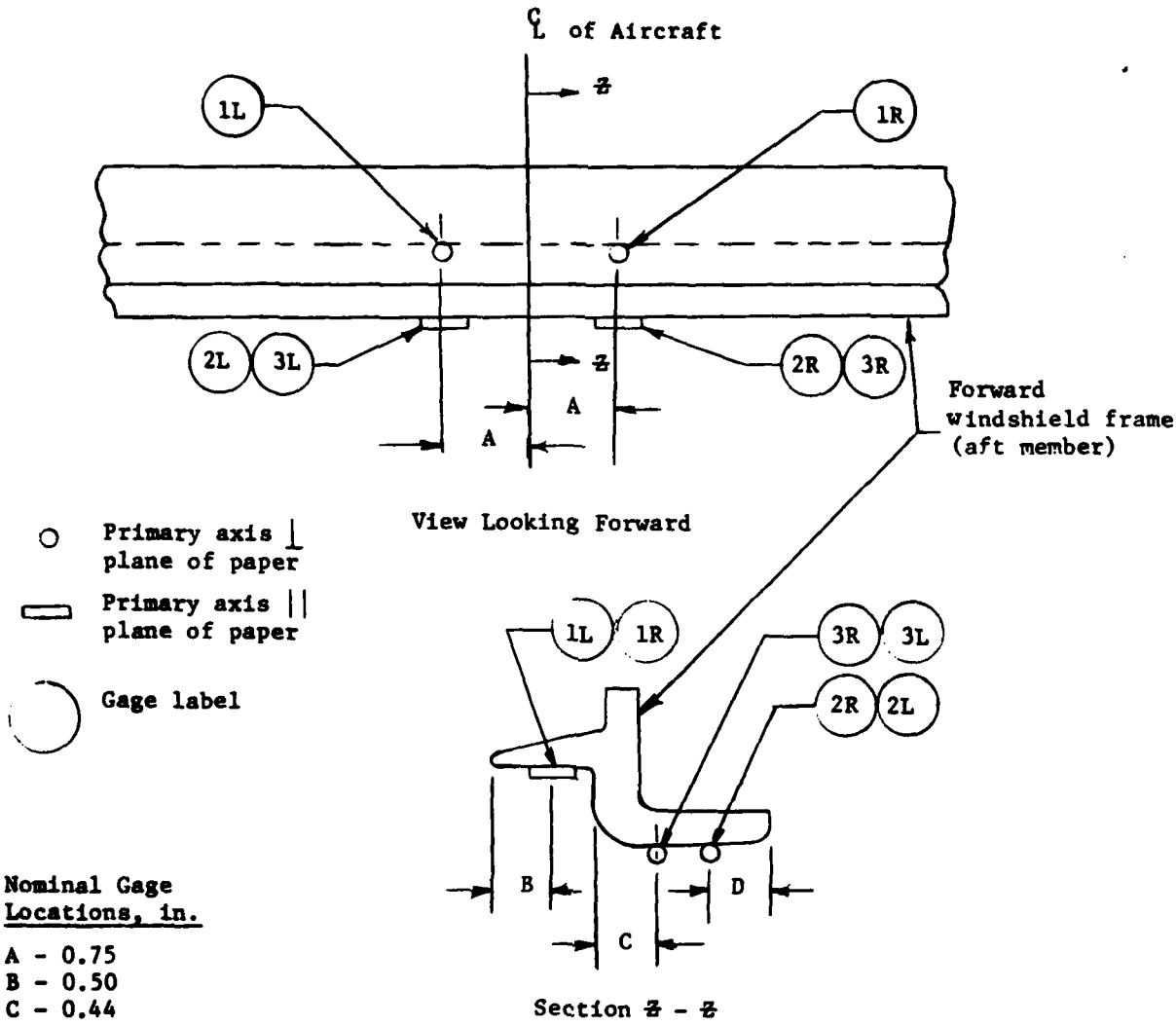
All strain gages were disconnected from lead lines to the data acquisition area and connected directly to a BLH portable strain indicator for the purpose of measuring minute residual strain levels. These readings were taken just before and just after each test to evaluate the permanent deformation resulting from each test.

Gap Measurements

Before and after each test, measurements were made of the canopy frame to windshield frame clearance at nine locations as shown in Figure 6 to monitor structural member deformation during the tests.

3.5 IMPACT LOCATIONS

The six impact locations, three on the forward windshield and three on the forward canopy (Figure 7),were chosen to minimize the number of test articles required to characterize the impact failure levels of each transparency. Impact locations 1, 2, and 3 on the forward windshield were chosen so that the failure impact energy and failure modes in these areas could be determined. Of primary concern was the strength of the transparency-edge attachment design and the method of fastening the windshield in its



Nominal Gage Locations, in.

A - 0.75
B - 0.50
C - 0.44
D - 0.50

Measured location of each gage listed in Table 2

Figure 5. Strain Gage Locations and Designation.

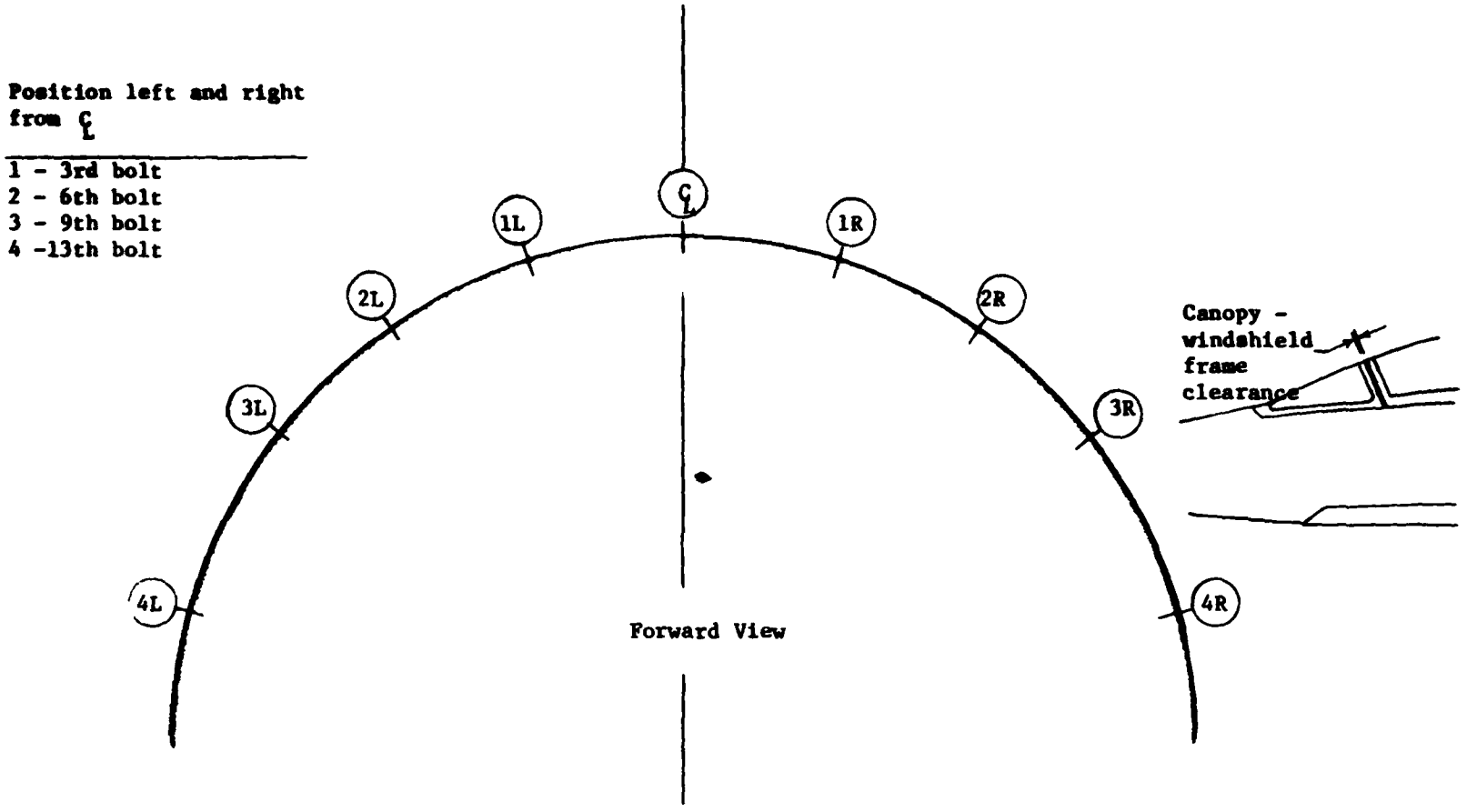
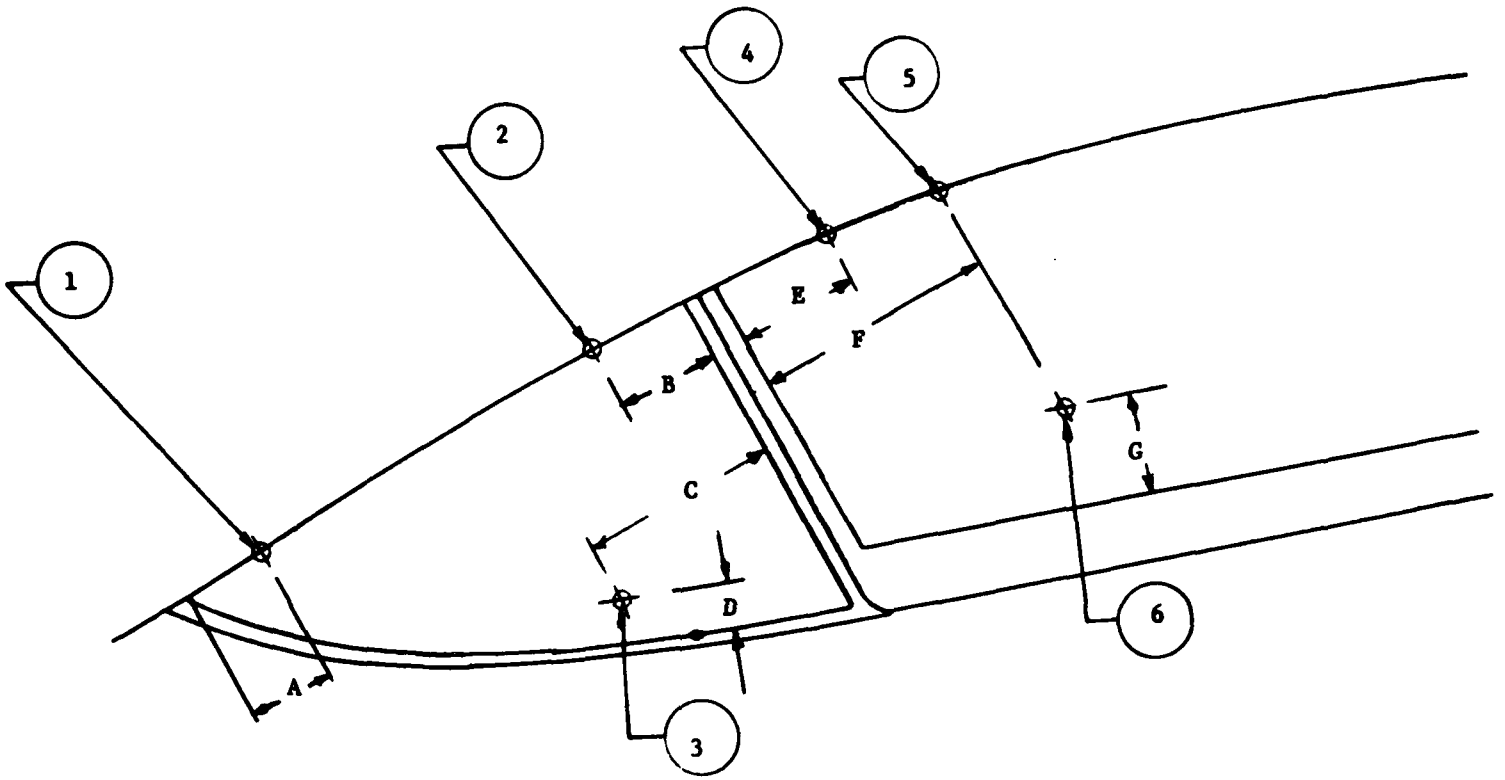


Figure 6. Canopy-Windshield Clearance Measurement Locations.



Notes: (1) Impact points 1, 2, 4, and 5 on fuselage centerline
(2) All dimensions in inches, as measured along transparency surface.

A - 6.125
B - 6.25
C - 9.875
D - 3.00
E - 7.00
F -12.55
G - 6.00

Figure 7. Bird Impact Test Locations.

frame (see Figure 8 and 9). Of a secondary concern was the strength of the frame itself but it was doubtful whether sufficient energy could be imparted to the frame in these tests to cause failure due to the potentially low failure velocities of the transparency. No shots were conducted at an impact location at the vertical-horizontal centerline of the windshield since Northrop Corporation had conducted its series of tests in 1968 at this location, and sufficient data was available from their test report (Reference 1). The no-failure velocity for the horizontal-vertical centerline impact location of the current windshield design was 319 knots in the Northrop tests.

The forward canopy impact locations, 4 and 6, were also chosen to characterize the edge attachments and frame strength. Location 5 was chosen to provide data for an impact as far aft from the canopy bow frame as possible while still allowing the bird to impact fully on the canopy at a relatively large angle of incidence. The forward edge of the canopy is restrained only between a forward arch and retainer that is riveted to the arch; no fasteners pass through the transparency or its edges in this area (see Figure 9). There was some concern that the transparency might pull out of the frame along the leading edge so impact location 4 was chosen to determine if such a tendency did exist.

The side edge attachments consist of a fiberglass overlay transitioning into a hinge node arrangement (see Figure 10). The transparency mounted nodes interlock with alternating nodes in the canopy frame side rails. A retainer pin passes through holes in the nodes parallel to the canopy frame, locking the sides of the transparency in place. Impact location 6 was selected to determine the response of the transparency-edge attachment bond and the transparency-frame nodes to bird impact.

(1) W. G. Shirreffs, "T-38 Bird Impact Resistivity Tests," NOR-68-121, August 1968.

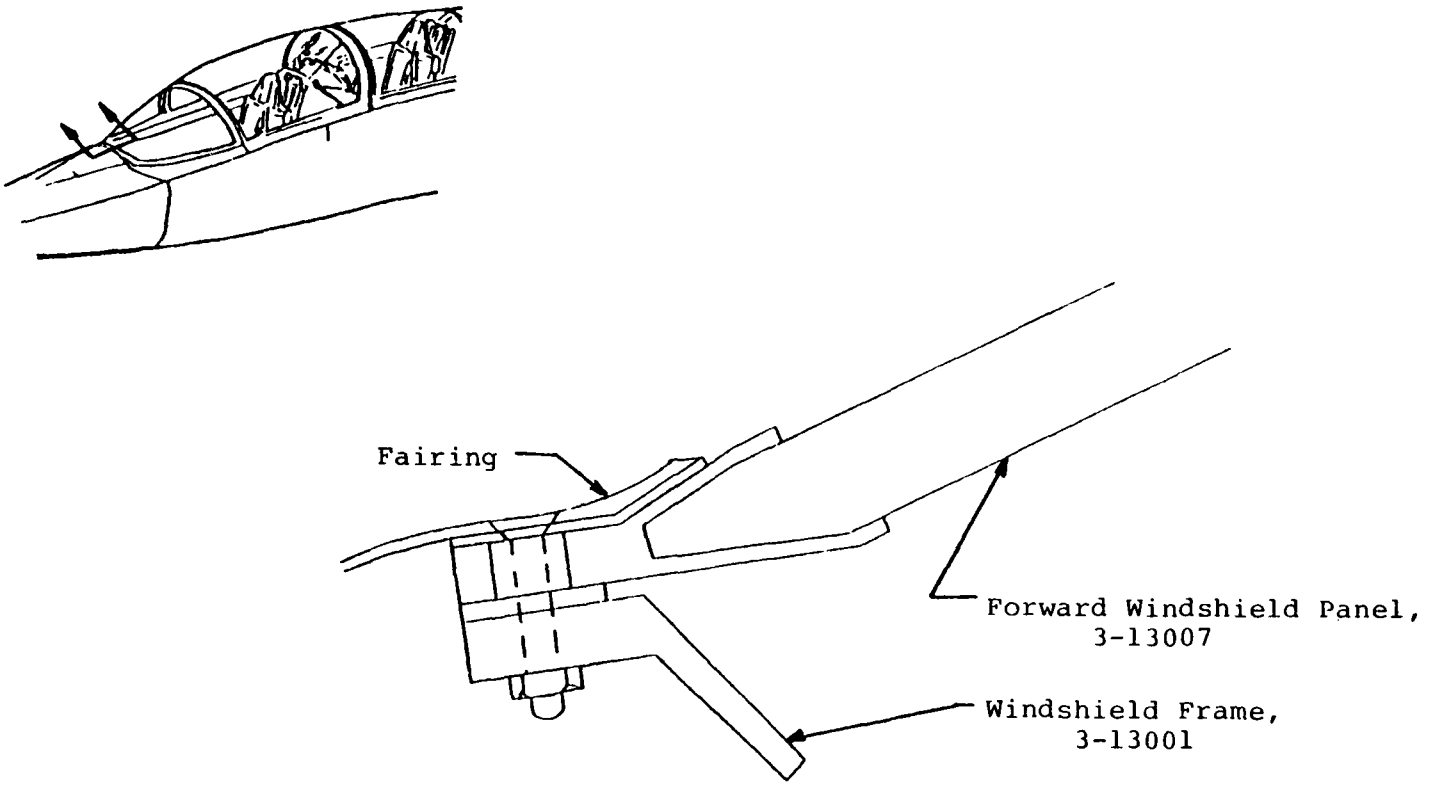
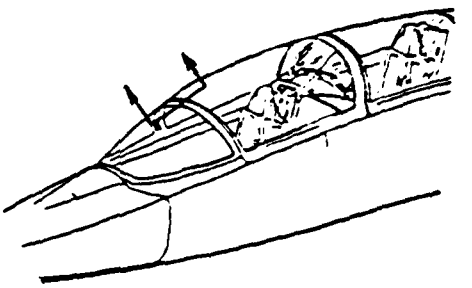


Figure 8. T-38 Forward Windshield Leading Edge Attachment.



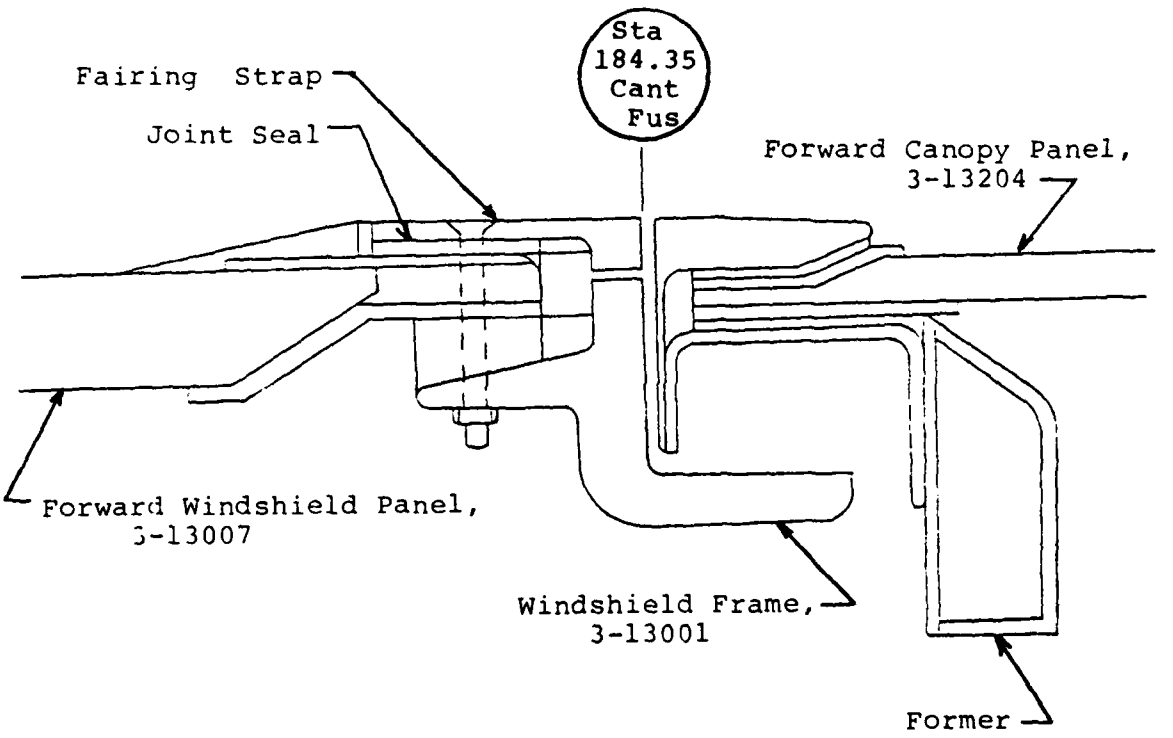


Figure 9. T-38 Forward Windshield Aft Edge and Forward Canopy Leading Edge Attachments.

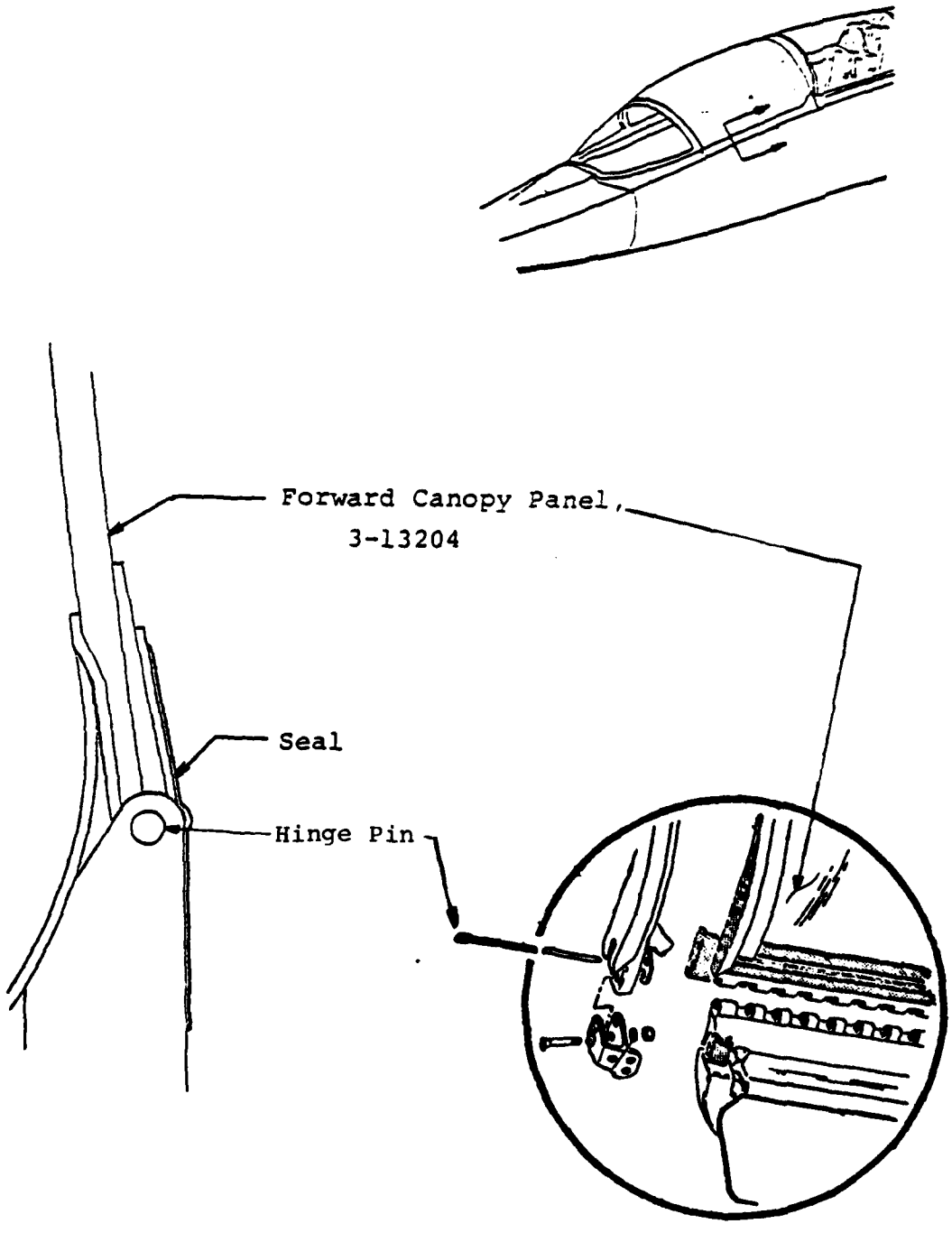


Figure 10. T-38 Forward Canopy Edge Attachment.

Impact locations 1, 2, 4, and 5 were all located along the aircraft horizontal centerline (butt line zero). Impact locations 3 and 6 required that the fuselage test fixture be yawed 15° clockwise.

The sequence in which the impact locations were tested was based on two considerations. To preserve the transparency/ support structure as long as possible, those impact locations (3 and 4) which were most likely to cause damage to the frame were scheduled late in the test sequence. The sequence was also arranged to minimize the frequency of transparency change-out and test module relocation.

3.6 IMPACT VELOCITIES

The initial impact velocities for each impact location were selected prior to the initiation of testing on the basis of previous testing conducted by Northrop on T-38 windshields, tests on other aircraft transparency sytems, and an analysis of flat panel birdstrike test results. The initial velocities were selected so as to be below the expected failure velocities of the transparencies at the desired impact locations when utilizing a nominal four pound bird. The impact velocities for each impact location were to be increased on succeeding shots until the transparency failed. By using this step method of increasing the impact velocity until failure was achieved, the energy required to induce failure for each impact location could be established within a known range. The failure energy range would exist between the highest velocity at which failure had not occurred and the velocity at which failure occurred. For this test program, a bird weight of 4.00 ±0.1 pound was used for all tests.

The on-site test director for the Flight Dynamics Laboratory was responsible for determining the velocity of each succeeding shot, after the initial shot, until failure occurred. Subsequent velocity increases were to be made so as to minimize the number of shots required at each impact location without causing the failure energy range to become so large as to become meaningless.

The impact energy was evaluated in terms of the kinetic energy

$$KE = \frac{1}{2} MV^2$$

where

KE ≡ kinetic energy available at impact

M ≡ mass of bird

V ≡ velocity of bird as measured prior to impact.

SECTION 4
EXPERIMENTAL RESULTS

The results of the test sequence to establish the birdstrike capability of the existing T-38 forward transparencies is summarized in Table 1. The test results are presented in chronological order and the significance of each test is summarized. The gap measurements are summarized in Table 2. Additional test data, including strain gage data, and test detail is presented in References 4 and 5.

Individual test results are summarized in the following paragraphs. Data sheets for each test are presented in Appendix A. Sketches and photographs documenting the failure associated with each impact location are presented in Appendix B.

Test No. 632

Test No. 632 was conducted at impact location 1 with a desired velocity of 210 knots and an actual velocity of 208 knots. No apparent damage resulted to the forward windshield or its support structure. The bird attitude was pretty good except for a lowering of the forward portion prior to impact resulting in the initial contact being made with the metal structure approximately four inches below the windshield. There were no gap measurements made between the windshield arch and canopy frame.

Test No. 633

Test No. 633 was the second impact at location 1 and the velocity was to be increased to 250 knots but the actual velocity

(4) R. M. Watt, "Bird Impact Testing of Stretched Acrylic Transparencies for the T-38 Aircraft," AEDC-TSR-79-V58, Arnold Engineering Development Center, Tullahoma, Tennessee, October 1979.

(5) R. M. Watt, Data Package, "AFFDL-T-38 Canopy Bird Impact Test, Project No. V415-35," Wright-Patterson Air Force Base, Ohio, October 1979.

TABLE 1

SUMMARY OF T-38 BASELINE BIRDSTRIKE TESTING

Shot Number/ Date	Location	Velocity				Bird Weight		Kinetic Energy $Ft\text{-}lb_f$	Remarks
		Expected		Actual					
		Kts	Fps	Kts	Fps	Gms.	Lbs.		
632 6 Aug 79	1	210	355	208	351	1805	3.98	7614	First bird shot, existing W/S capability > 208 kts at shot Location 1.
633 7 Aug 79	1	250	422	236	400	1817	4.01	9963	Catastrophic failure velocity at Location 1 $\leq$ 236 kts.
634 9 Aug 79	5	110	186	112	189	1818	4.01	2224	First shot Location 5, no visible damage, bird orientation questionable.
635 10 Aug 79	5	145	245	146	246	1813	4.00	3759	Catastrophic failure at aft-bow frame.
636 13 Aug 79	4	85	144	84	142	1807	3.98	1246	First shot Location 4, no visible damage.
637 14 Aug 79	4	110	186	107	181	1818	4.01	2040	No visible damage except for surface abrasions.
638 15 Aug 79	4	135	228	130	220	1819	4.01	3014	Surface abrasions, no other visible damage.
639 16 Aug 79	4	155	263	154	260	1814	4.00	4199	Surface abrasion larger, failure had been expected.
640 17 Aug 79	4	180	304	178	300	1812	3.99	5576	Catastrophic failure at or near shot Location 5. Instructor's windshield cracked by bird debris.
641 22 Aug 79	2	190	321	191	322	1834	4.04	6504	First shot Location 2. Windshield bruised, gap changed.
642 23 Aug 79	2	230	388	224	378	1880	4.01	8897	Catastrophic failure, bird and windshield debris in cockpit. Module canted 15° to right for remaining shots.
643 24 Aug 79	6	110	186	105	177	1825	4.02	1956	Surface abrasions but no visible damage to angle nodes.
644 27 Aug 79	6	145	245	141	238	1818	4.01	3527	Canopy failed with cracking radiating into hinge area but no actual failure of any nodes; acrylic broken out from impact location back to frame.
645 29 Aug 79	3	200	338	200	338	1812	3.99	7078	No failure, bird remains in frame gap but not cockpit.
646 29 Aug 79	3	250	422	247	417	1811	3.99	10774	Catastrophic failure with all acrylic going inside fiberglass edge. Attachment broken as was part of ramp in area of failure.

TABLE 2. SUMMARY OF GAP MEASUREMENTS FOR T-38 BASELINE TESTING.

Gap Location	Gap Measurement	Shot Number 632	633	634	635	636	637	638	639	640	641	642	643	644	645	646
4L	Before		.092			.180	.185	.187	.180	.175	.175	.215	.105	.122	.125	.125
	After		.100			.184	.175	.183	.150	.150	.210	.231	.125	.125	.125	.125
	Δ		+.008			+.004	-.010	-.004	-.030	-.025	+.035	+.016	+.020	+.003	-	-
3L	Before		.090			.148	.154	.154	.140	.142	.100	.155	.100	.104	.150	.120
	After		.090			.150	.156	.142	.130	.109	.175	.167	.109	.127	.120	.122
	Δ		-			+.002	+.002	-.012	-.010	-.033	+.075	+.012	+.009	+.023	-.030	+.002
2L	Before		.057			.097	.102	.098	.086	.088	.042	.098	.094	.080	.082	.080
	After		.060			.094	.100	.090	.077	.050	.120	.073	.097	.100	.082	.080
	Δ		+.003			-.003	-.002	-.008	-.009	-.038	+.078	-.025	+.003	+.020	-	-
1L	Before		.043			.097	.090	.085	.075	.050	.002	.075	.058	.087	.080	.077
	After		.047			.085	.086	.082	.073	.010	.109	.046	.080	.094	.085	.096
	Δ		+.003			-.012	-.004	-.003	-.002	-.040	+.107	-.029	+.022	+.007	+.005	+.019
CL	Before	See Note 1 Below	.043			.099	.105	.100	.098	.084	.000	.082	.068	.059	.075	.071
	After		.043			.099	.096	.090	.100	.050	.105	.025	.068	.075	.075	.075
	Δ		-			-	-.009	-.010	+.002	-.034	+.105	-.057	-	+.016	-	+.004
1R	Before		.047			.088	.087	.077	.085	.073	.005	.078	.065	.063	.077	.075
	After		.047			.087	.080	.084	.072	.030	.105	.032	.069	.073	.080	.068
	Δ		-			-.001	-.007	+.007	-.013	-.043	+.100	-.046	+.004	+.010	+.003	-.007
2R	Before		.069			.091	.087	.100	.091	.080	.015	.100	.075	.073	.090	.090
	After		.076			.090	.087	.090	.087	.058	.100	.057	.075	.092	.103	.086
	Δ		+.007			-.001	-	-.010	-.004	-.022	+.085	-.043	-	+.019	+.013	-.004
3R	Before		.070			.135	.138	.142	.134	.124	.087	.148	.102	.106	.122	.118
	After		.074			.038	.137	.130	.139	.109	.175	.148	.103	.111	.133	.122
	Δ		+.004			+.003	-.001	-.012	+.005	-.015	+.092	-	+.001	+.005	+.011	+.004
4R	Before		.090			.162	.167	.175	.172	.164	.120	.175	.100	.105	.113	.113
	After		.086			.165	.164	.161	.175	.154	.185	.175	.105	.114	.130	.116
	Δ		-.004			+.003	-.014	+.003	-.010	-.010	+.065	-	+.005	+.009	+.017	+.003

Notes: 1. No data was taken for test 632, 634, and 635.

was 236 knots. All components were the same as in Test No. 632. The transparency failed catastrophically with approximately 30 to 40 percent of the bird penetrating the cockpit. The bird orientation prior to impact looked good and impact was at the desired location. Analysis of the films showed little, if any, apparent motion in the forward fuselage. Visual observation revealed no apparent damage to the windshield support structure or mounting hardware. The transparency had cracked through to its leading edge at the front bulkhead center screw location. This was discovered when the transparency was removed from the frame. The windshield arch-canopy frame gap measurements are shown in Table 2. The test established that the catastrophic failure velocity for impact location 1 is equal to or less than 236 knots. The characteristics of the failure are shown in Figures B-1, B-2, and B-3.

Test No. 634

Test No. 634 was the first test at impact location 5 on the forward canopy. The forward windshield which failed in Test No. 633 was replaced, although the left side hinge pin could not be fully engaged. The desired impact velocity was 110 knots while the actual was 112 knots. The impact produced no visible damage and the bird remained almost intact after impact. Examination of the films revealed that the bird was yawed to the left 45° and pitched up 30° at impact. Initial impact was approximately 1-1/2 to 2 inches low and to the left of the canopy centerline. The effect of these deviations is unknown except that the energy imparted to the transparency was less than that which would have been imparted if the bird would have been on target and in the ideal end-on orientation.

Test No. 635

Test No. 635 was the second impact at location 5 for the forward canopy. All test hardware remained the same as in Test No. 634. The desired impact velocity was 145 knots while the actual was 146 knots. The left windsheild hinge pin was not fully engaged and the forward canopy rear view mirrors were removed to prevent transparency failure due to impact with the

attachment screws. The canopy failed catastrophically at the aft bow frame without any bird penetration of the cockpit area. One large piece of acrylic (10"x5"), two smaller pieces (2"x4") and several 1"x1" pieces were found inside the cockpit. The bird was not completely pulverized as several large pieces were found intact behind the test fixture. Review of the motion pictures revealed that a stress wave formed following impact and traveled aft reaching the aft arch of the forward canopy at approximately the same time that the bird carcass passed over. A reflection wave of significant magnitude traveled forward over the pilot's head position as the transparency failure occurred. The bird orientation at impact looked good. The characteristics of the failure are documented in Figures B-4 and B-5.

Test No. 636

Test No. 636 was the first shot at impact location 4 on the forward canopy. The forward canopy broken in Test No. 635 was removed along with its frame and replaced by a canopy and frame obtained from Davis-Monthan Air Force Base, Arizona. The actual impact velocity was 84 knots in comparison to a desired impact velocity of 85 knots. The low initial velocity was selected due to the uncertainty as to how the leading edge would react in terms of strength or edge restraint. It was felt that since the canopy changes shape slightly at the leading edge and transitions into the edge attachment area, this could be a potential failure area. Also it was unclear how the means of restraining the leading edge of transparency would react and whether the transparency would be pulled loose when subjected to a bird impact close to the leading edge. The canopy rear view mirrors were again removed for the reasons cited in Test No. 635 and remained off for the remainder of the test program. The bird impact produced no visible damage and the bird remained totally intact after impact. Analysis of the high speed film revealed that the bird was slightly off center to the right at impact and created a wave motion in the transparency that ceased when the bird broke contact with the

transparency approximately above the pilot's head position. The magnitude of the wave was small and there was no visible deflection of the forward arch.

Test No. 637

Test No. 637 was the second impact at location 4 and used the test hardware from Test No. 636. The actual impact velocity was 107 knots versus 110 knots desired. The transparency did not fail although abrasions were found at and below the point of impact and on the forward windshield. The bird remained largely intact although some remains were found on the transparency surface. The films revealed the bird had initially impacted on the forward windshield and the windshield and canopy frames although it appeared that most of the bird's mass had impacted on the canopy. No apparent wave motion was started by the bird impact as had been present in Test No. 636 although there was some oscillation of the transparencies visible due to the reflected light from the camera lights. There was no visible deflection of the windshield or canopy frame.

Test No. 638

Test No. 638 was the third impact at location 4 with the same test hardware as in tests 636 and 637. The desired velocity was increased to 135 knots while the actual velocity obtained was 130 knots. No transparency failure occurred although the films revealed a noticeable deflection of approximately 1.5 to 2 inches in the forward canopy. The wave appeared to travel the length of the canopy as the bird moved along the surface. The bird departed the canopy above the pilot's head position and the wave died out upon reaching the aft canopy bow. The bird impact was off-target to the left of centerline by approximately 1.5 inches but was not low as in Test No. 637. There was no discernible motion in the windshield or canopy frame.

Test No. 639

Test No. 639 was the fourth impact at location 4 with the same test hardware. Some surface abrasion remained from Test

No. 638 and there was a small scratch on the canopy located approximately 14.5 inches aft of the leading edge and running parallel to the leading edge which was discovered after Test No. 638. The actual velocity was 154 knots in comparison to a desired velocity of 155 knots. There was no visible damage other than abrasion marks and increased bird remains on the transparency. The high speed films revealed that the bird had initially impacted on the windshield frame, but not the windshield, and then traveled aft until it departed the canopy above the pilot's head position. There was a noticeable deflection of the canopy bow frame (0.125 to 0.250 inches) with visible rippling throughout the canopy and windshield, but there was no pronounced single wave motion as had occurred in Test No. 636.

Test No. 640

Test No. 640 was the fifth shot at impact location 4 and achieved an actual velocity of 178 knots versus the 180 knots desired. All test hardware had been previously utilized in tests 636, 637,638, and 639. There was little deflection of the canopy prior to failure in the impact area. The initial impact was at the forward canopy frame causing some flattening of the forward former in the centerline area. Cracks in the acrylic appear to originate in the leading edge of the transparency propogating outboard and aft prior to complete failure of the acrylic. The majority of the bird penetrated the canopy and impacted with enough force on the plexiglass shield directly in front of the instructor's windshield to break the instructor's windshield. Since the 0.5 inch plexiglass was not in direct contact with the instructor's windshield, it must have flexed under the impact forces and impacted with sufficient force to crack the instructor's windshield. Beside the bird, there was a large amount of acrylic in the forward cockpit that would have presented a hazard to the crew member, including one piece approximately 4 square inches in size. The change in gap between the windshield frame and forward canopy bow was sufficient to be visibly noticeable. The characteristics of the failure are shown in Figures B-6 and B-7.

Test No. 641

Test No. 641 was the first shot at impact location 2 on the forward windshield. A new canopy replaced the one damaged in Test No. 640 and a new instructor's windshield was installed with a 1.00-inch-thick plexiglass protective shield replacing the 0.50-inch shield previously used. The forward windshield retaining pin on the left side was not fully inserted so that approximately 2.00 inches remained exposed. It appeared that the pin was bent slightly preventing its full insertion despite repeated attempts. It was felt that this would have little effect on the test results since the pin on the right side was fully engaged and the test would take place away from the area where the pin was not engaged. The forward canopy was a field reject in that it was oversize and required a variation in the accepted installation procedure. The aft shoulder of the canopy was thicker than either of the previous forward canopies that had been installed. This required over-sizing several of the aft mounting slots and leaving off the flat washers normally installed to allow use of the standard fasteners. The forward retainer was fastened in place using aluminum pop rivets instead of the normal aluminum solid rivets. The canopy was probably a little longer than the previous two tested (length measurements were not made prior to installation in the frame) even though the side hinge pins fit in the frame and transparency attachment nodes without problems.

The possibility that the transparency was longer than the previous two canopies became evident when the pretest windshield/canopy gap was measured. At the centerline location there was no clearance and there was insufficient gap between the rear of the canopy and the instructor windshield frame to allow aft readjustment of the canopy. Following the test, the forward windshield/canopy gap had increased as had the canopy/instructor windshield gap, suggesting that the canopy and frame had absorbed some energy and, in turn, been compressed in the process. There was a bruise on the exterior of the windshield but no other visible damage. There was bird debris inside the cockpit which

entered through the gap between the forward windshield and the canopy frames. The high-speed cameras revealed that there was considerable vertical deflection of the windshield frame aft arch which allowed the bird remains to enter through the gap created. There was no visible deformation in the windshield or canopy frame during the inspection following the test. The windshield itself had some wave motion which rapidly dampened out without any visible damage resulting. Although the initial bird impact was slightly below the target impact location, the majority of the bird's mass appeared to contact the transparency at the desired impact point.

Test No. 642

Test No. 642 was the second shot at impact location No. 2 on the forward windshield. All test hardware was the same as was used for Test No. 641. The planned impact velocity was 230 knots and the actual impact velocity was 224 knots. The windshield failed catastrophically with failure initiating under the point of impact and propogating aft to the arch frame and forward towards the front bulkhead. Several pieces of the acrylic windshield, including some large pieces, entered the cockpit and would have impacted the pilot. Approximately 50 percent of the bird mass entered the cockpit and would have impacted the pilot. This test established the threshold of failure at this location at less than 224 knots. The characteristics of the failure are shown in Figures B-8, B-9, and B-10.

Test No. 643

Test No. 643 was the first shot at impact location No. 6 on the forward canopy. The test module was rotated 15 degrees clockwise to the line of flight of the bird. The student windshield which experienced failure on test 642 was replaced with a new windshield for this test. The planned impact velocity was 110 knots and the actual impact velocity was 105 knots. The bird was slightly yawed at impact and the impact location was slightly aft of the desired impact location. Response to the imapct resulted in some oscillatory movement of canopy and instructor's windshield support

structure. There was no visible damage to the canopy, the hinge nodes, and the fiberglass edge attachment. Scuff marks resulting from the impact were visible on the canopy and bird feathers were caught between the side rail and canopy towards the rear portion of the forward canopy. It was concluded that the canopy and side hinge node attachment system can successfully withstand the forces associated with impact at location 6 of a four pound bird at 105 knots with the test module yawed 15 degrees.

Test No. 644

Test No. 644 was the second shot at impact location No. 6 on the forward canopy. All test hardware was the same as was used for shot No. 643. The planned impact velocity was 145 knots and the actual impact velocity was 141 knots. The bird was partially out of the bag and appendages were flailing at impact. However, the center of gravity of the bird was on target. The canopy failed by fracture. Failure appeared to initiate at the frame and propogated rapidly with large pieces of acrylic breaking out under the bird. Considerable deflection along the hinge line was observed as the bird traveled aft. A majority of the bird and much of the plexiglass remained outside the cockpit (for this condition of no aerodynamic flow). Approximately 20 to 25 percent of the broken acrylic was found inside the cockpit including two pieces 3x4 inches in the front cockpit and several pieces 2x4 inches in the rear cockpit. About 20 percent of the bird mass was either inside the cockpit or trapped in the framework. There was no apparent damage to the hinge pin or nodes. The fiberglass material was torn from a point where the clear area of the panel starts to a point just forward of the 25th node. Cracking of the acrylic occurred under the fiberglass material. This test established the upper limit on the failure velocity for this condition at 141 knots. The characteristics of the failure are shown in Figures B-11, B-12, B-13, and B-14.

Test No. 645

Test No. 645 was the first shot at impact location No. 3 on the forward windshield. The test module was rotated 15 degrees

clockwise to the line of flight of the bird. The impact point had originally been defined 11-3/4 inches forward of the aft frame leading edge. It was necessary to redefine this dimension to 9-7/8 inches (Reference Figure 7) due to the traverse limits on the AEDC test fixture. The planned impact velocity was 200 knots and the actual impact velocity was 200 knots. The test was conducted with the failed canopy from test No. 644 in the test module. This was necessitated by the lack of a suitable replacement canopy. A sheet metal cover was taped in place over the broken canopy to keep the debris from entering the cockpit through the opening. There was no apparent damage to the windshield and the only sign of impact was a small amount of bird debris on the transparency and frame. The bird bounced and was somewhat intact after impact.

Test No. 646

Test No. 646 was the second shot at impact location No. 3 on the forward windshield. All test hardware was the same as was used for shot No. 645. The planned impact velocity was 250 knots and the actual impact velocity was 247 knots. A section of the windshield approximately 6x14 inches was broken out at the aft rear corner. It appeared that all of the broken acrylic entered the cockpit as did 20 to 30 percent of the bird mass. Some spalling of the inside surface of the acrylic around the fracture occurred. The fiberglass edge was broken out around the boundary of the fracture area as was the outer surface ramp along the aft arch area. This test established the upper limit of the capability at less than 247 knots for this impact condition. Characteristics of the failure are documented in Figures B-15, B-16, and B-17.

SECTION 5
CONCLUSIONS

Based upon the testing of the existing T-38 stretched acrylic forward transparencies, the following conclusions can be reached:

1. The 0.600" stretched acrylic forward windshield can withstand nominal four pound bird impacts at velocities ranging from about 320 knots at the horizontal/vertical center of the windshield to approximately 210 knots at the aft edge of the transparency. The specific critical velocity is impact location dependent.

2. The 0.230" stretched acrylic forward canopy can withstand nominal four pound bird impacts at velocities ranging from about 165 knots at the centerline leading edge of the canopy to about 125 knots at a location along the centerline 14" aft of the leading edge. Again, the critical velocity is impact location dependent.

3. The existing framework for the forward windshield and forward canopy was capable of withstanding the impact forces that the transparencies were subjected to without catastrophic failure. The ability of the support structure to withstand significantly higher impact velocities cannot be determined from this test series.

SECTION 6

REFERENCES

1. W. G. Shirreffs, "T-38 Bird Impact Resistivity Tests," NOR-68-121, August 1968.

2. Blaine S. West, "Design and Testing of F-111 Bird Resistant Windshield/Support Structure, Volume I - Design and Verification Testing," AFFDL-TR-76-101, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, October 1976.

3. A. P. Berens, B. S. West, and M. A. Turella, "On a Probabilistic Model for Evaluating the Birdstrike Threat to Aircraft Crew Enclosure," UDR-TR-78-124, University of Dayton Research Institute, Dayton, Ohio, November 1978.

4. R. M. Watt, "Bird Impact Testing of Stretched Acrylic Transparencies for the T-38 Aircraft," AEDC-TSR-79-V58, Arnold Engineering Development Center, Tullahoma, Tennessee, October 1979.

5. R. M. Watt, Data Package, "AFFDL-T-38 Canopy Bird Impact Test, Project No. V415-35," Wright-Patterson Air Force Base, Ohio, October 1979.

APPENDIX A

T-38 FORWARD TRANSPARENCY EXISTING CAPABILITY TEST DATA

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T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 6 AUG 79 Test No. 632

Impact Pt.	1
Planned Impact Velocity	210 knots
Actual Impact Velocity	208 knots
Bird Weight	1805 grams
Kinetic Energy	7614 ft-lbs.
Ambient Temperature	93°F
Relative Humidity	94/79 (51%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus.	53E-D2	
Student W/S	PN 3-13014-3	SWU-602	9/77
Student Canopy	PN 2-13201-49	SWU-2925	7/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	No. 1		
Student Canopy Frame	PN 2-13201-507	S/N 5867	(No. 1)*
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	1st Bird Test
Student Canopy	1st Bird Test
Instr. W/S	1st Bird Test
Instr. Canopy	1st Bird Test

IV. PRE-TEST OBSERVATIONS

Gages 1L & 1R are Axial Gages

*Canopy Frame No. 1 (Identification Painted on).

V. POST TEST OBSERVATIONS

1. No visible damage to transparency or support structure.
2. Large pieces of bird intact after test.
3. Bird orientation "pretty good." Front of bird slightly low (apparently due to legs hanging down). Caused first contact to be made on metal structure 4" below windshield.

VI. SIGNIFICANCE OF TEST

Establish existing windshield capability at location No. 1 to be greater than 208 knots.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 7 AUG 79 Test No. 633

Impact Pt.	1
Planned Impact Velocity	250 knots
Actual Impact Velocity	236 knots
Bird Weight	1817 grams
Kinetic Energy	9963 ft-lbs.
Ambient Temperature	93°F
Relative Humidity	96/82 (55%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus.		53E-D2
Student W/S	PN 3-13014-3	SWU-602	9/77
Student Canopy	PN 2-13201-49	SWU-2925	7/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	No. 1		
Student Canopy Frame	PN 2-13201-507	S/N 5867	(No. 1)
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	Test 632 (Location 1 on W/S)
Student Canopy	Test 632
Instr. W/S	Test 632
Instr. Canopy	Test 632

IV. PRE-TEST OBSERVATIONS

V. POST TEST OBSERVATIONS

1. Catastrophic failure (see sketch and photograph, Figures B-1 and B-2).
2. 30-40% of bird penetrated.
3. No visible damage to support structure or mounting hardware.
4. Bird location and orientation looked good.
5. Appears to be little, if any, motion in forward fuselage.
6. Measured gap change between windshield frame and canopy frame (see Table 2).
7. Transparency was cracked through to edge at front bulkhead center screw location.

VI. SIGNIFICANCE OF TEST

Establish catastrophic failure velocity for Shot Location 1 to be less than or equal to 236 knots.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 9 AUG 79 Test No. 634

Impact Pt.	5
Planned Impact Velocity	110 knots
Actual Impact Velocity	112 knots
Bird Weight	1818 grams
Kinetic Energy	2224 ft-lbs.
Ambient Temperature	96°F
Relative Humidity	96/80 (50%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2
Student W/S	PN 3-13014-3 SWU-534 1/77
Student Canopy	PN 2-13201-49 SWU 2925 7/73
Instr. W/S	
Instr. Canopy	
Student W/S Frame	PN 3-13014-5 S/N 5830
Student Canopy Frame	PN 2-13201-507 S/N 5867 (No. 1)
Instr. Canopy Frame	PN 2-13300-1 S/N 5100

III. HARDWARE TEST HISTORY

Student W/S	1st Bird Test
Student Canopy	Test 632, 633
Instr. W/S	Test 632, 633
Instr. Canopy	Test 632, 633

IV. PRE-TEST OBSERVATIONS

1. Hinge pin on left side students W/S not fully engaged (≈ FWD 10-12" is not engaged).

2. 10th and 12th attach screws on student W/S arch have inadequate thread engagement (measured from left sill).

V. POST TEST OBSERVATIONS

1. No visible damage.
2. Bird remained almost totally intact.
3. Bird yawed 45° left, pitched 30° up at impact.
4. Bird low (1 1/2 - 2" rough estimate) and to left of centerline.

VI. SIGNIFICANCE OF TEST

1. Test results questionable because of bird orientation and location.
2. Assuming shot represents valid test, establishes that student canopy capability at location 5 is greater than 112 knots.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 10 AUG 79 Test No. 635

Impact Pt.	5
Planned Impact Velocity	145 knots
Actual Impact Velocity	146 knots
Bird Weight	1813 grams
Kinetic Energy	3759 ft-lbs.
Ambient Temperature	84°F
Relative Humidity	90/79 (62%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU-534	1/77
Student Canopy	PN 2-13201-49	SWU-2925	7/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	PN 3-13014-5	S/N 5830	
Student Canopy Frame	PN 2-13201-507	S/N 5867	(No. 1)
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	Test 634
Student Canopy	Test 632, 633, 634
Instr. W/S	Test 632, 633, 634
Instr. Canopy	Test 632, 633, 634

IV. PRE-TEST OBSERVATIONS

1. Canopy frame mirrors removed - attach screws are long and provide small clearance to canopy transparency.

2. Hinge pin on left side students W/S not fully engaged (Ref. note for test 634).

V. POST TEST OBSERVATIONS

1. Canopy failed at aft bow-frame (see photograph and sketch, Figures B-4 and B-5).

2. Zero bird penetration.

3. One large piece acrylic inside (10" x 15") in front floor area plus two intermediate 2" x 4" pieces (one in floor, one in front of instructor's windshield). Several smaller particles 1" x 1" or less inside.

4. Bird not completely pulverized, some fairly large pieces intact.

VI. SIGNIFICANCE OF TEST

Establishes that student canopy capability at Impact Location 5 is less than or equal to 146 knots.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 13 AUG 79 Test No. 636

Impact Pt.	4
Planned Impact Velocity	85 knots
Actual Impact Velocity	84 knots
Bird Weight	1807 grams
Kinetic Energy	1246 ft-lbs.
Ambient Temperature	83°F
Relative Humidity	84/71 (53%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU-534	1/77
Student Canopy	PN 2-13201-49	SWU-2933	9/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	PN 3-13014-5	S/N 5830	
Student Canopy Frame	No. 2		
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	Test 634, 635
Student Canopy	None
Instr. W/S	All tests this series.
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Hinge pin on left side students W/S not fully engaged.

2. Mirrors removed; sensors added to determine whether canopy would deflect into mirror mount screws. Clearance before shooting Rt. Side = .218"; Left Side = .313".

V. POST TEST OBSERVATIONS

1. No visible damage.
2. Bird remained totally intact.
3. Shot off to left of centerline approximately 2".
4. Clearance on mirror mount after test; right side = .212"*
   left side = .313"

*Difference in pre and post test measurements believed to be due to measuring accuracy.

VI. SIGNIFICANCE OF TEST

No significant damage due to 84 knot impact at Impact Location No. 4.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 14 AUG 79 Test No. 637

Impact Pt.	4
Planned Impact Velocity	110 knots
Actual Impact Velocity	107 knots
Bird Weight	1818 grams
Kinetic Energy	2040 ft-lbs.
Ambient Temperature	81°F
Relative Humidity	80/69 (58%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU 534	1/77
Student Canopy	PN 2-13201-49	SWU 2933	9/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	PN 3-13014-5	S/N 5830	No. 2.
Student Canopy Frame	No. 2.		
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	Test 634, 635, 636
Student Canopy	Test 636
Instr. W/S	All tests this series.
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Ref. Test No. 636.

V. POST TEST OBSERVATIONS

1. No canopy failure.

2. Abrasions at and below point of impact; also abrasions on forward windshield.

3. Some bird remains (blood and pulverized feathers) on canopy; large portion of bird landing intact to left rear of module.

4. Clearance on mirror mount after test: left side - 0.313"
right side - 0.212"

VI. SIGNIFICANCE OF TEST

No significant damage due to 107 knot impact at Impact Location No. 4.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 15 AUG 79 Test No. 638

Impact Pt.	4
Planned Impact Velocity	135 knots
Actual Impact Velocity	130 knots
Bird Weight	1819 grams
Kinetic Energy	3014 ft-lbs.
Ambient Temperature	75°F
Relative Humidity	71/77 (75%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU-534	1/77
Student Canopy	PN 2-13201-49	SWU 2933	9/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	PN 3-13014-5	S/N 5830	No. 2
Student Canopy Frame	No. 2		
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	Test 634, 635, 636, 637
Student Canopy	Test 636, 637
Instr. W/S	All tests this series.
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Lt. hinge pin for students W/S not fully engaged.

V. POST TEST OBSERVATIONS

1. Surface scratch running perpendicular to bird path. Not noticed prior to test.

2. Sealant along trailing edge of forward arch of canopy cracked - was cracked prior to test; separation distance appears uniform around transparency.

3. Mirror mount clearance: left side = 0.315"
   right side = 0.218".

4. Bruise on canopy extends almost to trailing edge.

5. Bird landed behind test fixture.

VI. SIGNIFICANCE OF TEST

No significant damage due to 130 knot impact at Impact Location No. 4.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 16 AUG 79 Test No. 639

Impact Pt.	4
Planned Impact Velocity	155 knots
Actual Impact Velocity	154 knots
Bird Weight	1814 grams
Kinetic Energy	4199 ft-lbs.
Ambient Temperature	83°F
Relative Humidity	71/84 (53%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU 534	1/77
Student Canopy	PN 2-13201-49	SWU 2933	9/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	PN 3-13014-5	S/N 5830	No. 2
Student Canopy Frame	No. 2		
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	Test 634, 635, 636, 637, 638
Student Canopy	Test 636, 637, 638
Instr. W/S	All tests this series.
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Surface scratch as noted after Test 638.
2. Surface abrasion from Test 638.

V. POST TEST OBSERVATIONS

1. Mirror mount screw clearance: left side = 0.315"
   right side = 0.220".
2. Forward retainer gap appeared unchanged.
3. Looks like impact on target.
4. Bird remains more scattered and more debris remained on canopy.
5. Surface scratch noted above does not appear to be any larger.

VI. SIGNIFICANCE OF TEST

No significant damage due to 154 knot impact at Impact Location No. 4.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 17 AUG 79 Test No. 640

Impact Pt.	4
Planned Impact Velocity	180 knots
Actual Impact Velocity	178 knots
Bird Weight	1812 grams
Kinetic Energy	5576 ft-lbs.
Ambient Temperature	81°F
Relative Humidity	74/84 (62%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU 534	1/77
Student Canopy	PN 2-13201-49	SWU 2933	9/73
Instr. W/S			
Instr. Canopy			
Student W/S Frame	PN 3-13014-5	S/N 5830	No. 2
Student Canopy Frame	No. 2		
Instr. Canopy Frame	PN 2-13300-1	S/N 5100	

III. HARDWARE TEST HISTORY

Student W/S	Tests 634 through 639 (6 previous)
Student Canopy	Tests 636 through 639 (4 previous)
Instr. W/S	All tests this series.
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Retaining pin fwd. W/S not in fully.
2. 5th shot on canopy in same location.
3. Surface scratch behind impact point not noticeably larger.

V. POST TEST OBSERVATIONS

1. Canopy broke out at forward former (see sketch and photograph, Figures B-6 and B-7).

2. Noticeable change in windshield - canopy frame gap (see Table 2).

3. Broke instructor's windshield and 0.5 inch plexiglass protective plate in front of it.

4. Slight flattening of forward former at the centerline and looks like rear frame of windshield flattened slightly.

5. Majority of bird in cockpit.

6. Appears mirror mounts might have touched canopy but no damage apparent above either one.

7. No readily visible change in seam along forward retainer and transparency does not appear to have pulled loose significantly if at all from the forward retainer.

VI. SIGNIFICANCE OF TEST

Catastrophic failure of forward transparency at or near point of impact on fifth shot at the location with incremental increasing velocities.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 22 AUG 79 Test No. 641

Impact Pt.	2
Planned Impact Velocity	190 knots
Actual Impact Velocity	191 knots
Bird Weight	1834 grams
Kinetic Energy	6504 ft-lbs.
Ambient Temperature	85°F
Relative Humidity	78/84 (64%)

II. TEST HARDWARE

Test Structure	Northrop Fws. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU 534	1/77
Student Canopy		FORT 092	1/76
Instr. W/S			No. 2
Instr. Canopy			No. 1
Student W/S Frame	PN 3-13014-5	S/N 5830	No. 2
Student Canopy Frame	PN 3-13201-507	S/N 5867	No. 1
Instr. Canopy Frame			

III. HARDWARE TEST HISTORY

Student W/S	Test 634-640 (6 previous-None as impact target)
Student Canopy	New (Broken shot No. 640)
Instr. W/S	New (Broken shot No. 640)
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Retaining pin on pilot's left side not fully inserted.

2. New canopy installed for this test is oversized at rear arch. No washers used on installation. Forward retainer installed with aluminum pop rivets in place of solid aluminum rivets.

3. Protective plexiglass plate 1.0 inch thick installed in front of instructor's windshield.

4. Note Table 2; zero gap between student windshield frame and canopy frame at centerline. There was not sufficient gap between canopy rear frame and instructor windshield frame to move canopy aft.

V. POST TEST OBSERVATIONS

1. Bird debris inside cockpit; entered along windshield/canopy gap since there is some debris between the frames on the inside around whole circumference.

2. Windshield - canopy gap opened up considerably (also rear gap appears wider - between rear of canopy and instructor's windshield).

3. Projectile appears to be on target at impact.

4. Bruise on exterior of windshield but no visible damage of a serious nature.

VI. SIGNIFICANCE OF TEST

1. Windshield damage velocity greater than approximately 190 knots.

2. Definite energy transfer to canopy frame - either from contact with windshield frame or from bird impact on frame or both.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 23 AUG 79 Test No. 642

Impact Pt.	2
Planned Impact Velocity	230 knots
Actual Impact Velocity	224 knots
Bird Weight	1820 grams
Kinetic Energy	8897 ft-lbs.
Ambient Temperature	78°F
Relative Humidity	75/82 (73%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU 534	1/77
Student Canopy		FORT 092	1/76
Instr. W/S			No. 2
Instr. Canopy			No. 1
Student W/S Frame	PN 3-13014-5	S/N 5830	No. 2
Student Canopy Frame	PN 3-13201-507	S/N 5867	No. 1
Instr. Canopy Frame			

III. HARDWARE TEST HISTORY

Student W/S	Test 634-641 (second shot as impact target)
Student Canopy	Shot No. 641
Instr. W/S	Shot No. 641
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Took measurement of fwd. canopy length & gap between aft end of fwd. canopy and leading edge of instructor's canopy. Pre-test length = 60 3/8 inches. Pre-test gap = 0.800 inches.
2. Left W/S hinge pin not fully engaged.
3. Took real time movie at 45° angle.
4. Trailing edge of W/S frame painted brown to highlight contrast with canopy frame.

V. POST TEST OBSERVATIONS

1. Windshield failed catastrophically with several pieces of plexiglass entering cockpit and breaking interior light (Reference Figures B-8, B-9, and B-10).

2. Bird debris sprayed on rear of student cockpit where seat would be and some even entered instructor's cockpit along sides of bulkhead.

3. Large piece of plexiglass on cockpit floor at approximate location of pilot's lap.

4. No Δ in gap between aft edge on forward canopy and leading edge of instructor's canopy but approximately 1/8" Δ in total canopy length.

5. Strain gauges at centerline pulled loose.

6. Magnetic compass mount bent aft and up slightly but compass not pulled loose.

VI. SIGNIFICANCE OF TEST

1. Failure point of forward windshield at or below 224 knots.

2. Apparently there is some energy transmitted to the canopy and frame during impact event.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 24 AUG 79 Test No. 643

Impact Pt.	6
Planned Impact Velocity	110 knots
Actual Impact Velocity	105 knots
Bird Weight	1825 grams
Kinetic Energy	1956 ft-lbs.
Ambient Temperature	88°F
Relative Humidity	87/76 (61%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU-486	10/76
Student Canopy		FORT 092	1/76
Instr. W/S			No. 2
Instr. Canopy			No. 1
Student W/S Frame	(No PN on Frame)		No. 1
Student Canopy Frame	PN 3-13201-507	S/N 5867	No. 1
Instr. Canopy Frame			

III. HARDWARE TEST HISTORY

Student W/S	New (Broken Test No. 642)
Student Canopy	Shot 641 and 642
Instr. W/S	Shot 641, 642
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Hinge pins on W/S fully engaged, new W/S installed.
2. Installation of canopy did not include any sealant and canopy used had been a UR exhibit for poor fit in field but was best fit could get in accordance with T.O.
3. Interior camera cannot be adjusted to photograph hinge pin reaction of canopy and frame.
4. Module turned 15° to right of projectile line of flight to expose shot location on side of canopy.
5. Gap on leading edge of frame between side rail and fwd. retainer of 0.178 in.

V. POST TEST OBSERVATIONS

1. Bruise on side of canopy - no visible damage, feathers caught in between side rail and canopy towards rear of forward canopy.

2. No visible damage to hinge nodes or fiberglass attachment.

3. Gap noted in No. 5 pre-test observations has opened to 0.200".

VI. SIGNIFICANCE OF TEST

Canopy and side hinge node attachment system can withstand the impact forces associated with an impact at Location 6 for a velocity of 105 knots when the module is offset 15° to pilot's right.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 27 AUG 79 Test No. 644

Impact Pt.	6
Planned Impact Velocity	145 knots
Actual Impact Velocity	141 knots
Bird Weight	1818 grams
Kinetic Energy	3527 ft-lbs.
Ambient Temperature	84°F
Relative Humidity	78/86 (70%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus.	53E-D2	
Student W/S	PN 3-13014-5	SWU-486	10/76
Student Canopy		FORT 092	1/76
Instr. W/S			No. 2
Instr. Canopy			No. 1
Student W/S Frame			No. 1
Student Canopy Frame	PN 3-13201-507	S/N 5867	No. 1
Instr. Canopy Frame			

III. HARDWARE TEST HISTORY

Student W/S	Test 643
Student Canopy	Test 641, 642, 643 (2nd shot at location 6)
Instr. W/S	Shot 641, 642, 643
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Test module offset 15° to pilot's right from bird gun centerline.
2. Canopy installation somewhat questionable since no sealants used and canopy had been UR exhibit for dimensional tolerance (Reference observation 2, page 57).
3. Inside camera now set to show hinge pin by using wide angle lens and removing part of student cockpit rear shroud.
4. Gap between side rail and fwd. former larger so that two pieces not touching each other.

V. POST TEST OBSERVATIONS

1. Canopy broke ≈ 8" behind impact PT (Reference Figures B-11, B-13, and B-14).

2. Majority of bird and several large pieces of plexiglass landed outside aircraft (including largest piece) two pieces inside front cockpit ≈ 3" x 4" with several small pieces 1 to 2" x 4" in rear cockpit.

3. Deflection shield mounted in place of shroud piece that was removed was covered with bird splatter and probably deflected most of the bird remains found in the rear cockpit.

4. No noticeable damage to hinge pin or nodes. Fiberglass layup on inside torn down from where clear area of panel starts to nodes just in front of 25th node - can see cracking in acrylic in between fiberglass layup (see sketch Figure B-12).

VI. SIGNIFICANCE OF TEST

1. Failure velocity for these conditions $\leq$ 141 knots.

2. 20-25% of acrylic inside cockpits with larger pieces found in fwd. cockpit. Even less would have been found in rear cockpit if instructor's inst. panel shroud had not been removed.

2. 20% of bird inside cockpit or caught in framework.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 29 AUG 79 Test No. 645

Impact Pt.	3
Planned Impact Velocity	200 knots
Actual Impact Velocity	200 knots
Bird Weight	1812 grams
Kinetic Energy	7078 ft-lbs.
Ambient Temperature	76°F
Relative Humidity	80/75 (79%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU-486	10/76
Student Canopy		FORT 092	1/76
Instr. W/S			No. 2
Instr. Canopy			No. 1
Student W/S Frame			No. 1
Student Canopy Frame	PN 3-13201-507	S/N 5867	No. 1
Instr. Canopy Frame			

III. HARDWARE TEST HISTORY

Student W/S	Test 643, 644 (1st shot at impact location)
Student Canopy	Test 641, 642, 643, 644 (Broken shot 644)
Instr. W/S	Test 641, 642, 643, 644
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. Canopy broken on Test 644 left installed to act as a spacer. No more suitable canopies to replace it with.
2. Impact point changed to 9 7/8" from leading edge of frame instead of 11 3/4" since table cannot traverse any further, 3" dimension retained.
3. W/S installed with gaskets but without sealants; hinge pins fully engaged on both sides.
4. Sheet metal cover taped over broken section of canopy to keep bird remains out of cockpit to facilitate post-shot clean up.

V. POST TEST OBSERVATIONS

1. W/S not broken - small amount of debris in arch crack but none in cockpit.
2. Piece of tape and plastic bag ≈ 2" in front of impact point with wet debris trailing back to arch.
3. No noticeable damage although corner piece may have shifted and let bird debris underneath (No. 28 T.O. 1T-38A-4-1 Figure 65, fairing, students windshield, L.H.).
4. Very little sign of impact on canopy except for slight bird debris on fwd. edge.
5. Bird pretty well messed up and in rear corner of building.

VI. SIGNIFICANCE OF TEST

No significant damage at 200 knots at impact Location No. 3.

T-38 TRANSPARENCY
EXISTING CAPABILITY TESTS

I. BASIC TEST DATA

Date 29 AUG 79 Test No. 646

Impact Pt.	3
Planned Impact Velocity	250 knots
Actual Impact Velocity	247 knots
Bird Weight	1811 grams
Kinetic Energy	10774 ft-lbs.
Ambient Temperature	86°F
Relative Humidity	80/89 (68%)

II. TEST HARDWARE

Test Structure	Northrop Fwd. Fus. 53E-D2		
Student W/S	PN 3-13014-3	SWU-486	10/76
Student Canopy		FORT 092	1/72
Instr. W/S			No. 2
Instr. Canopy			No. 1
Student W/S Frame			No. 1
Student Canopy Frame	PN 3-13201-507	S/N 5867	No. 1
Instr. Canopy Frame			

III. HARDWARE TEST HISTORY

Student W/S	Test 643, 644, 645 (2nd shot at impact location)
Student Canopy	Test 641, 642, 643, 644, 645 (Broken shot 644)
Instr. W/S	Tests 641, 642, 643, 644, 645
Instr. Canopy	All tests this series.

IV. PRE-TEST OBSERVATIONS

1. 2nd shot at impact location 3.
2. Canopy broken on test 644, left installed as a spacer with a piece of sheet metal taped over the hole.
3. W/S installed with gaskets but without sealants - hinge pins fully engaged on both sides.

V. POST TEST OBSERVATIONS

1. W/S broke as shown in sketch and photographs, Figures B-15, B-16, and B-17; appears that all material went inside the cockpit as did ≈ 20-30% of the bird.

2. Fiberglass edge broken out as was part of ramp where impact and failure occurred.

3. Had some spalling on the interior surface.

4. Largest piece inside found towards front of cockpit to pilot's right side.

5. Strain gauges torn loose by the shot on left side of arch and all wiring for gauges on the right side so will be no residual strain readings.

VI. SIGNIFICANCE OF TEST

1. Critical velocity at impact location No. 3 with fuselage canted 15 degrees is $\leq$ 247 knots.

APPENDIX B

GRAPHIC FAILURE DATA

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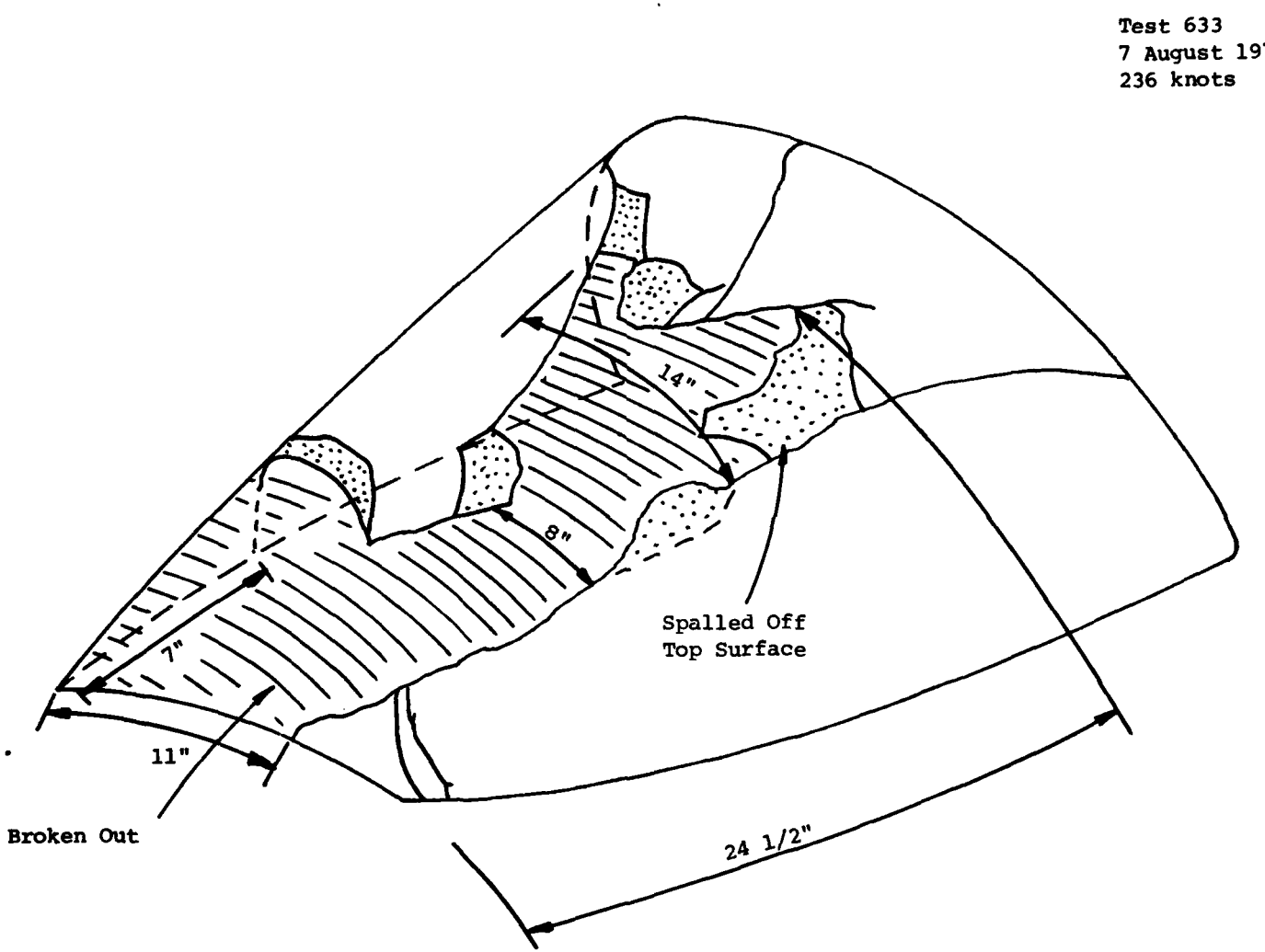


Figure B-1. Sketch of T-38 Forward Windshield After Test No. 633.

Figure B-2. T-38 Forward Windshield After Test No. 633.

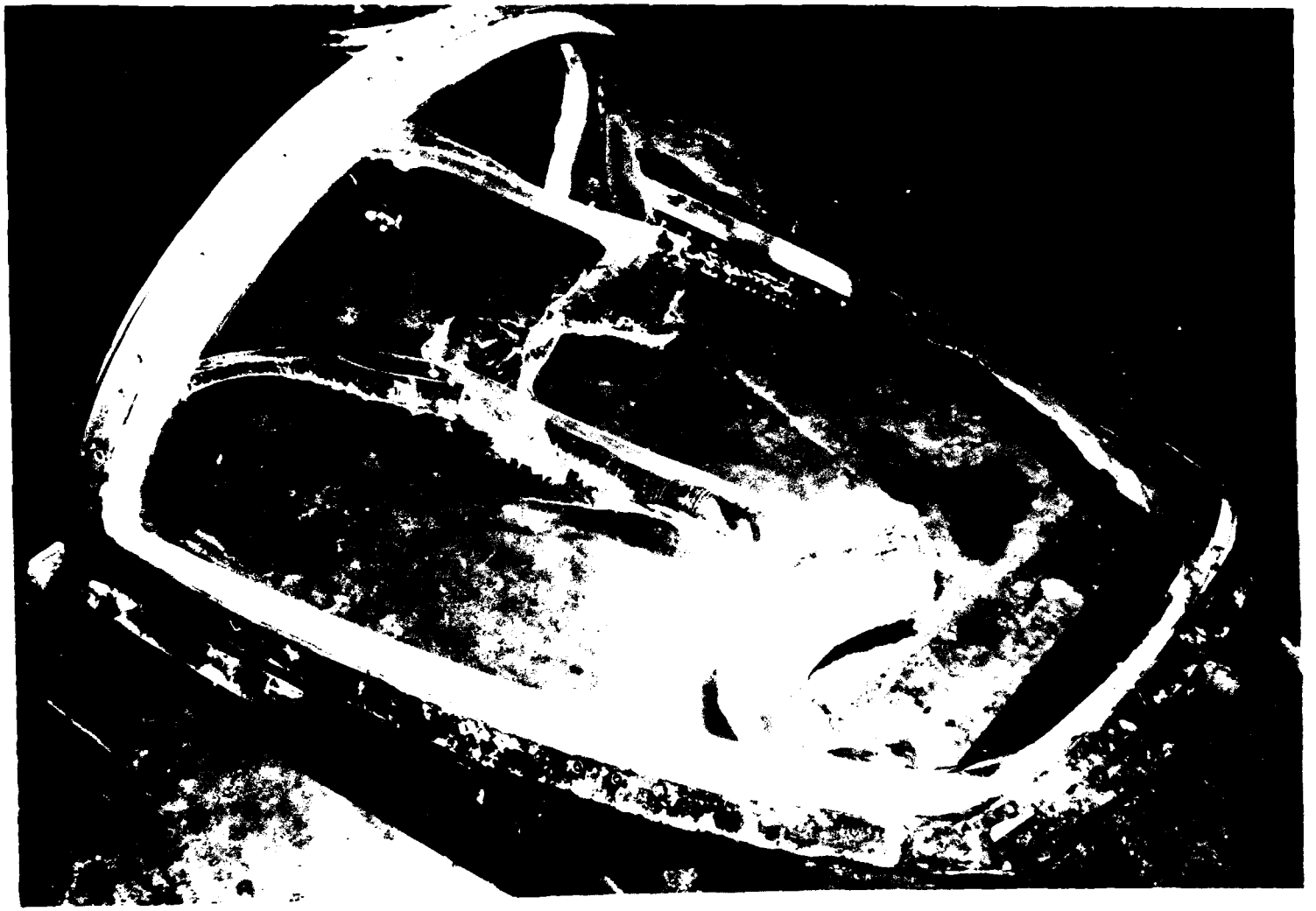


Figure B-3. Close-Up View of T-38 Forward Windshield After Test No. 633.

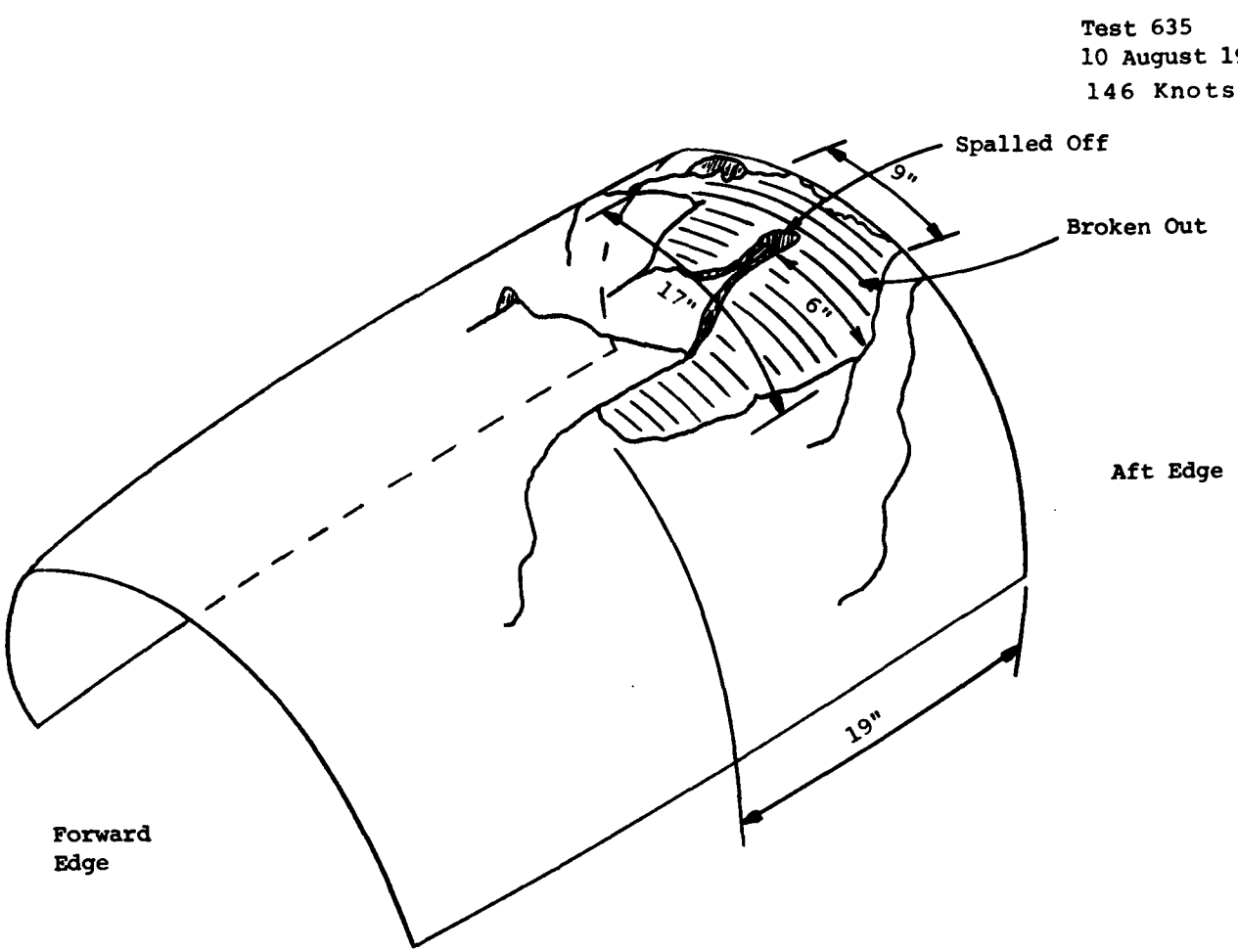


Figure B-4. Sketch of T-38 Forward Canopy After Test No. 635.

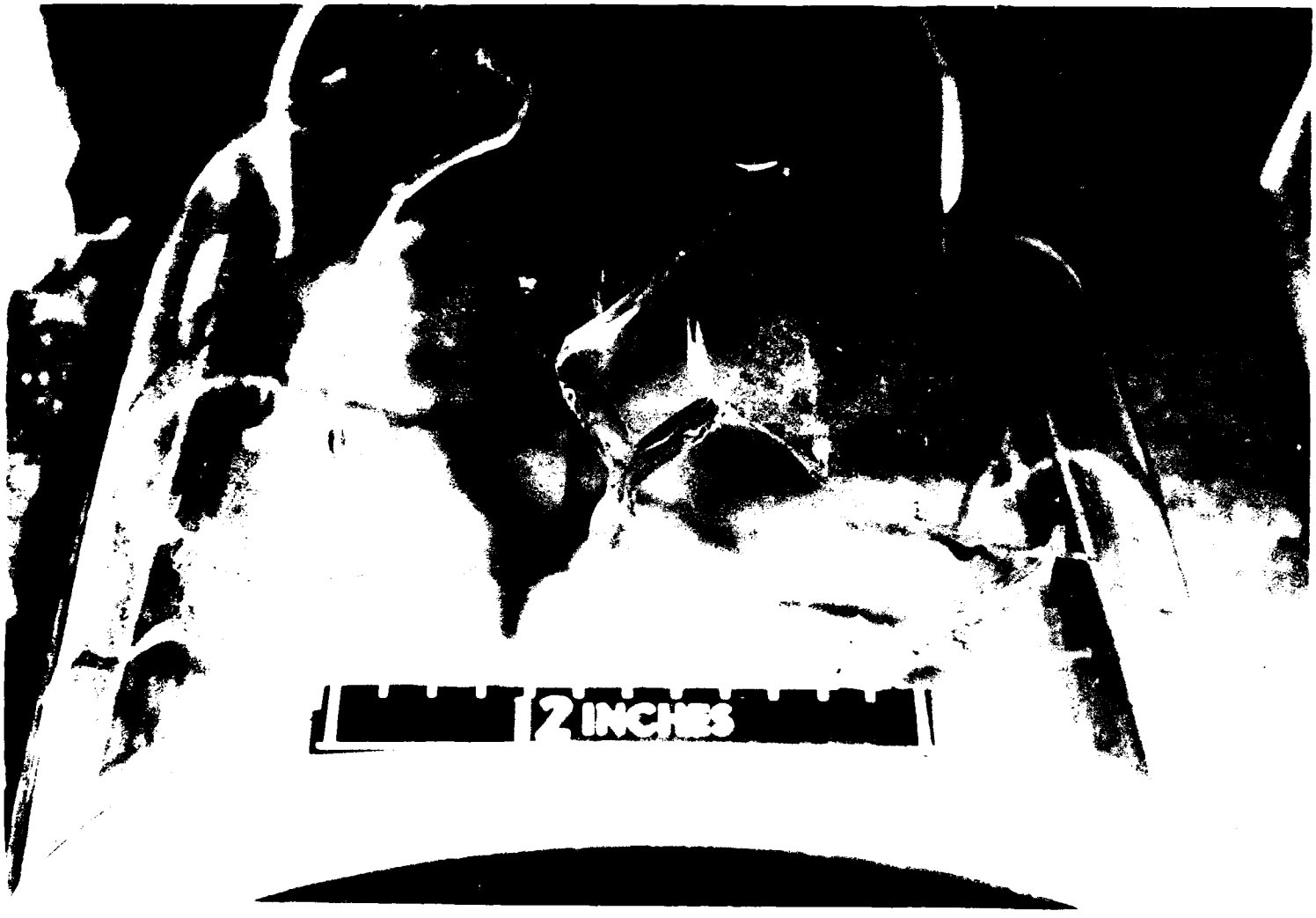


Figure B-5. T-38 Forward Canopy After Test No. 635.

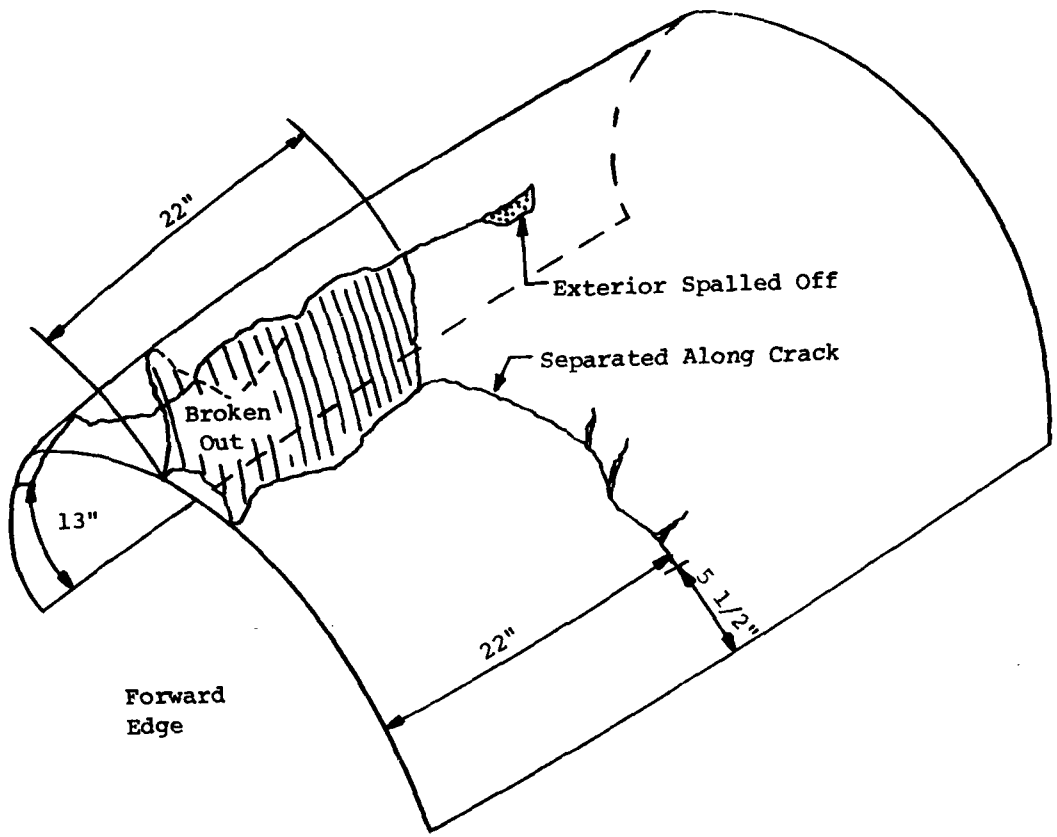


Figure B-6. Sketch of T-38 Forward Canopy After Test No. 640.

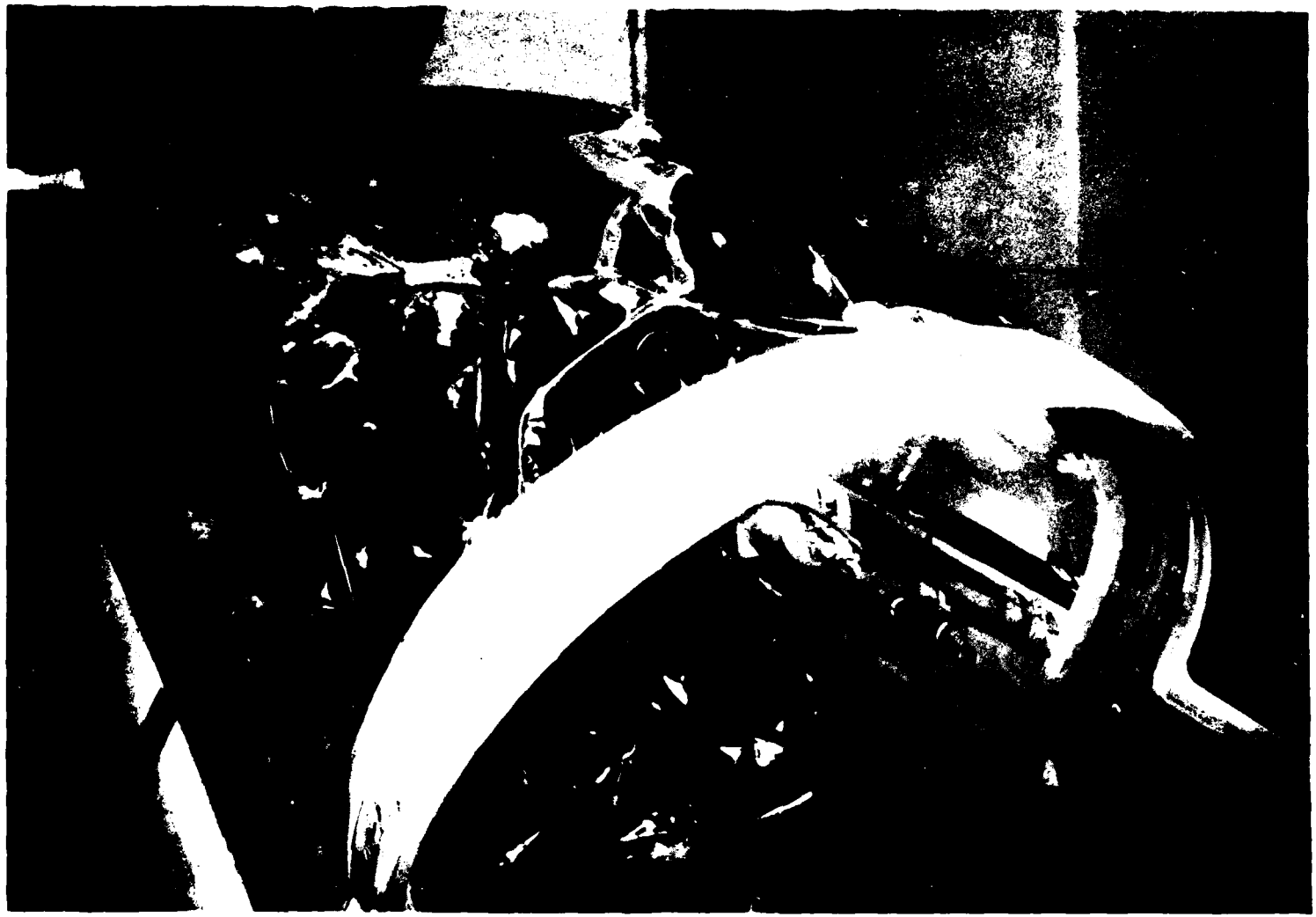


Figure B-7. T-38 Forward Canopy After Test No. 640.

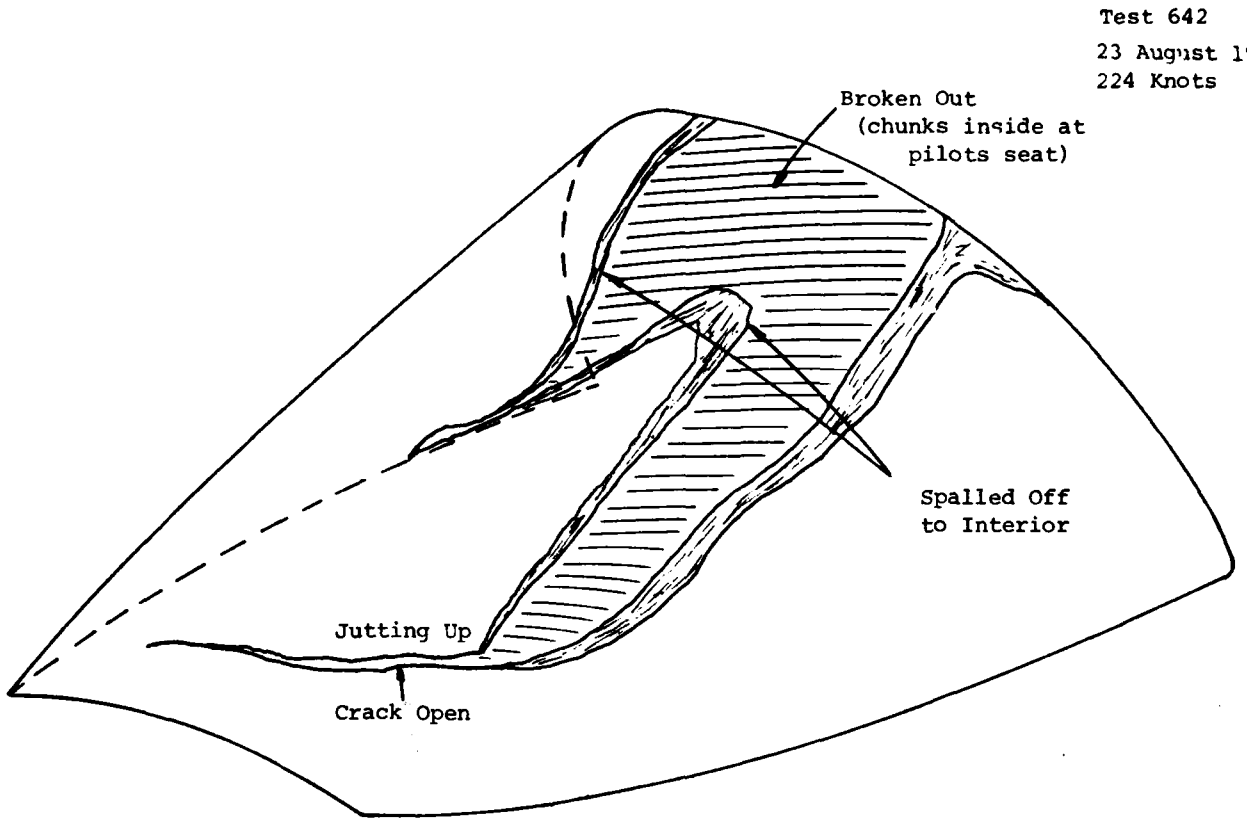


Figure B-8. Sketch of T-38 Forward Windshield After Test No. 642.

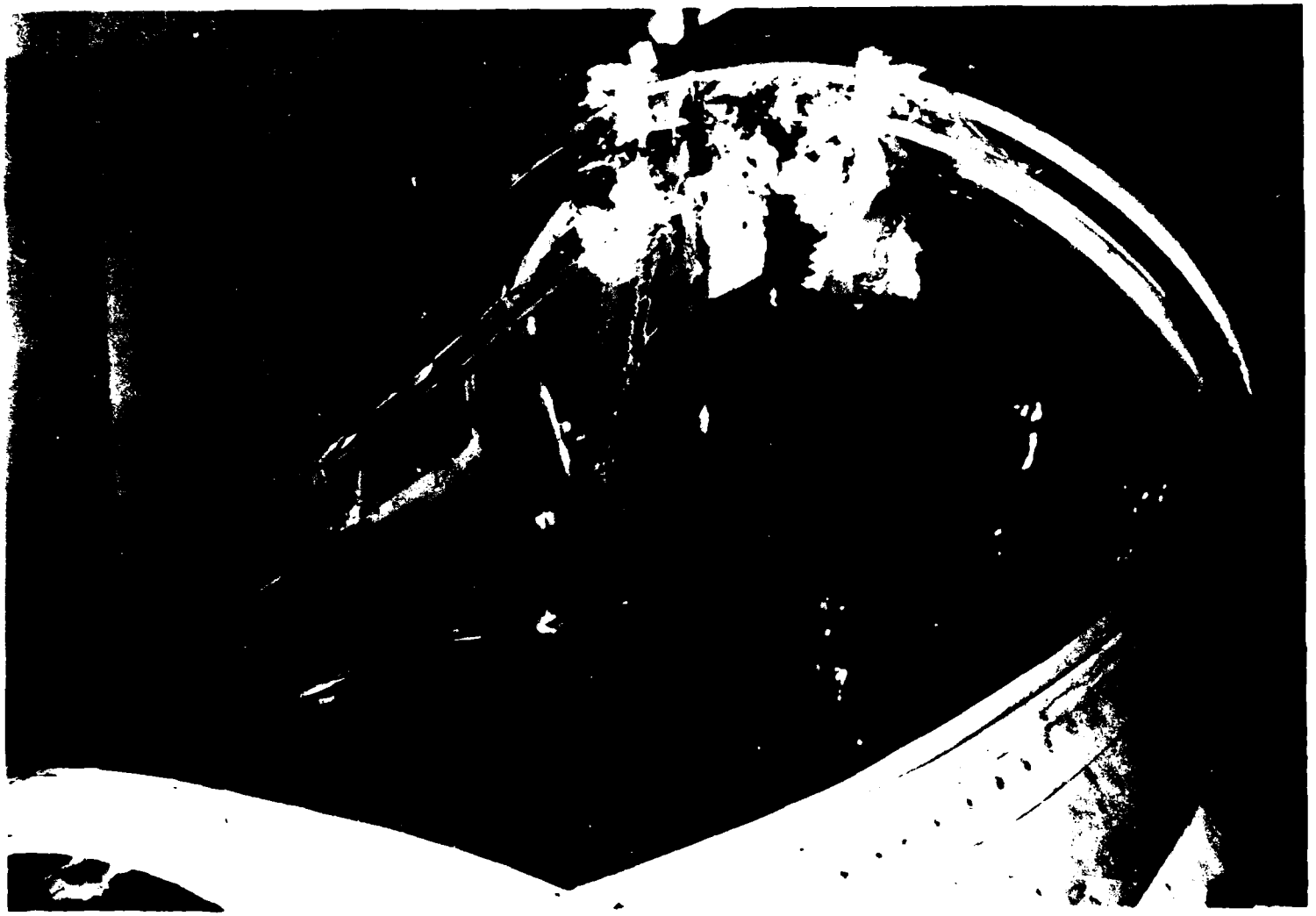


Figure B-9. T-38 Forward Windshield After Test No. 642.

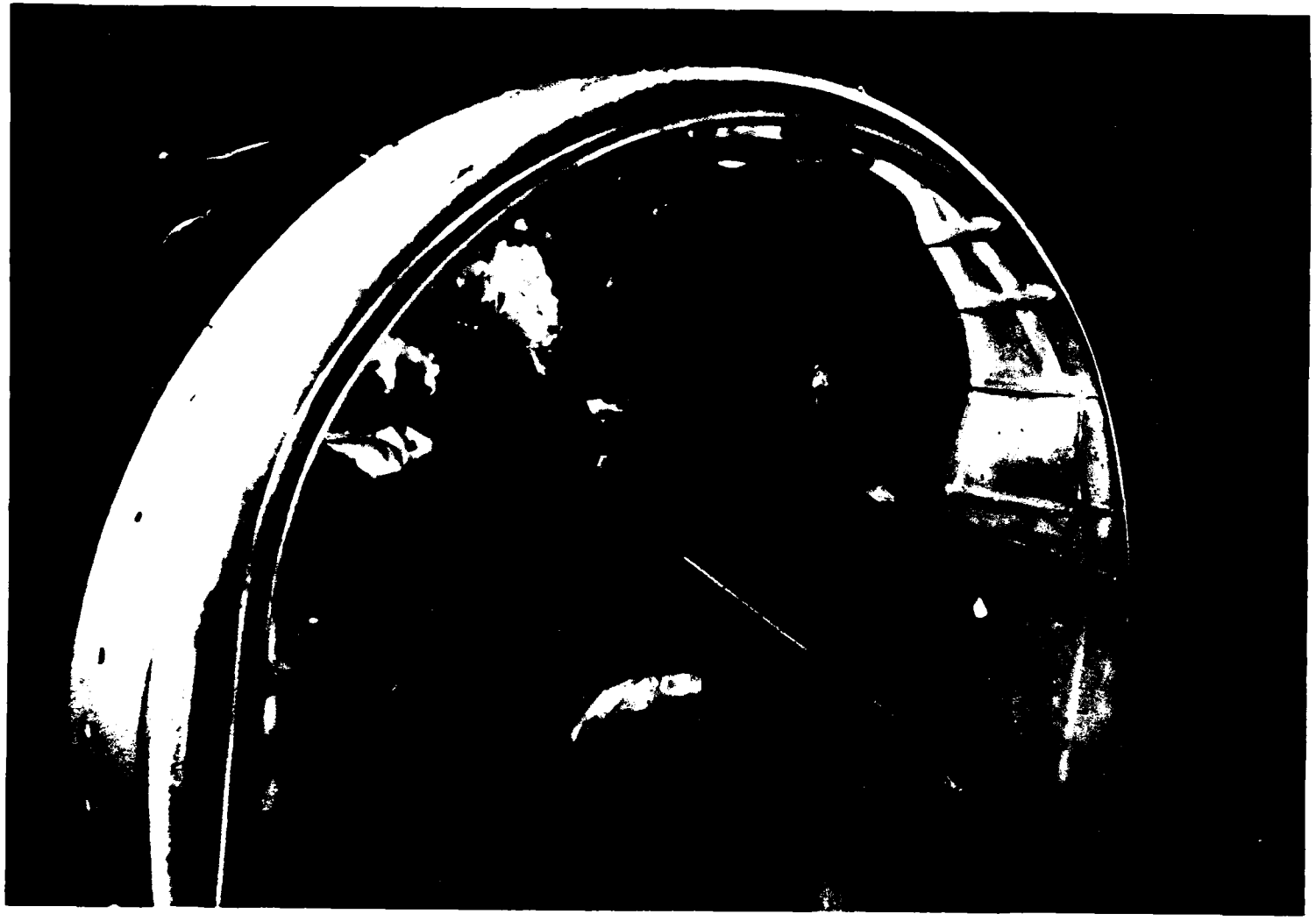


Figure B-10. T-38 Rear (Instructors) Windshield After Test No. 642.

Test 644
27 August 1979
141 Knots

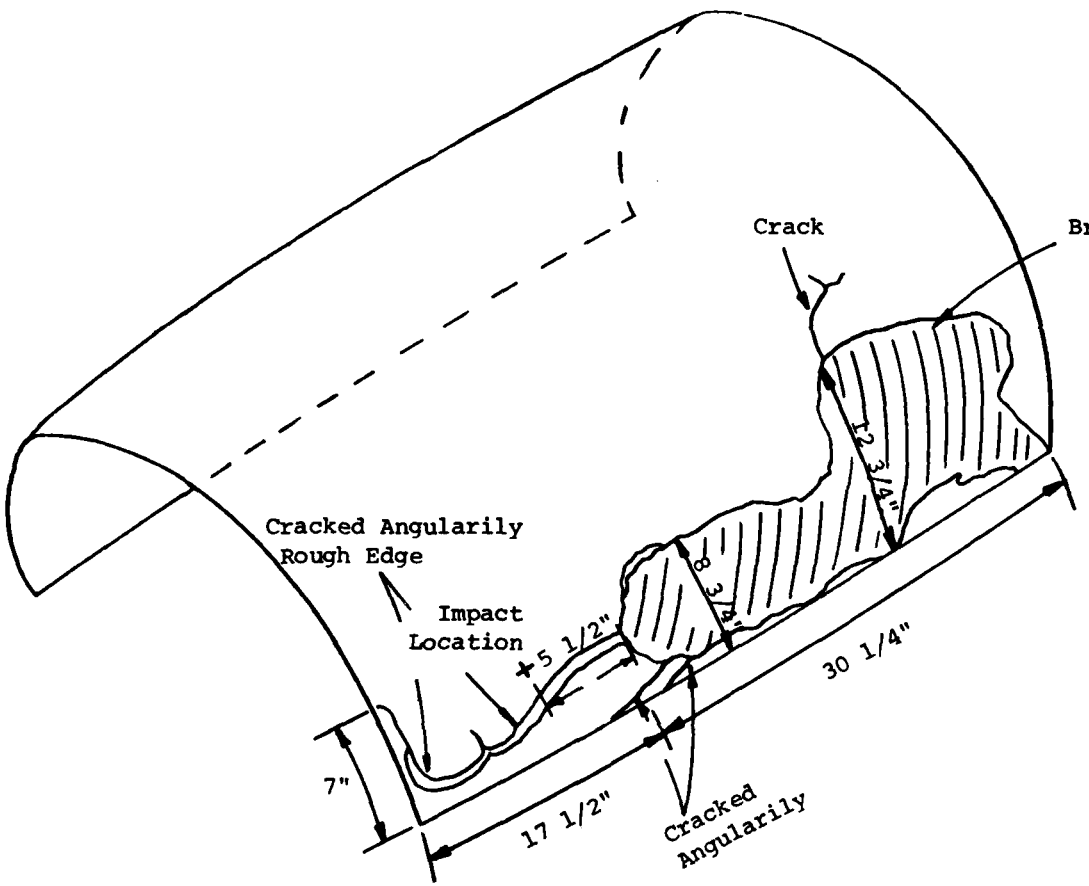
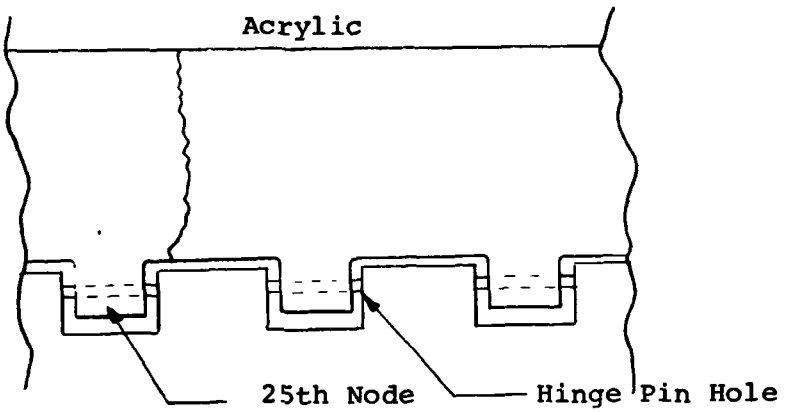


Figure B-11. Sketch of T-38 Forward Canopy After Test No. 644.



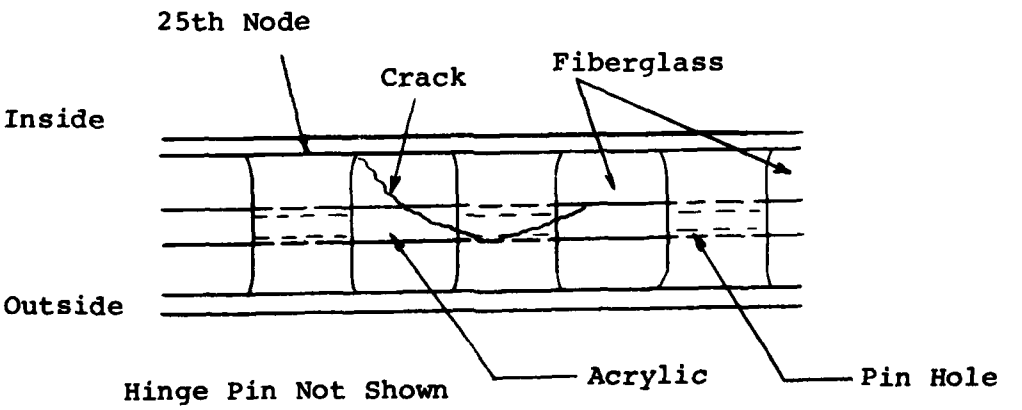


Figure B-12. T-38 Canopy Edge Failure Resulting from Test No. 644.

Figure B-13. T-38 Forward Canopy After Test No. 644.

Figure B-14. T-38 Forward Canopy After Test No. 644 (Following Canopy Removal).

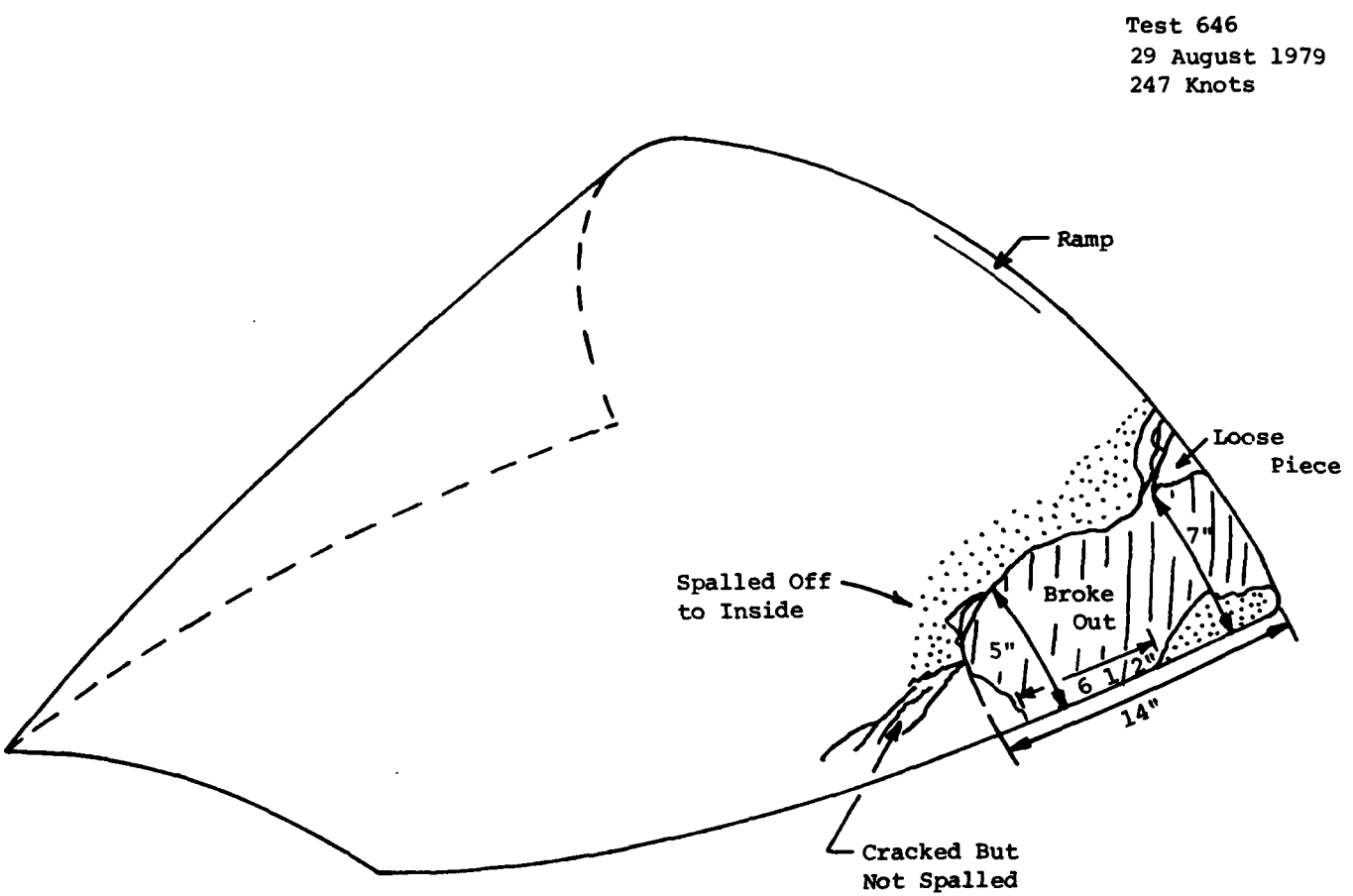


Figure B-15. Sketch of T-38 Forward Windshield After Test No. 646.

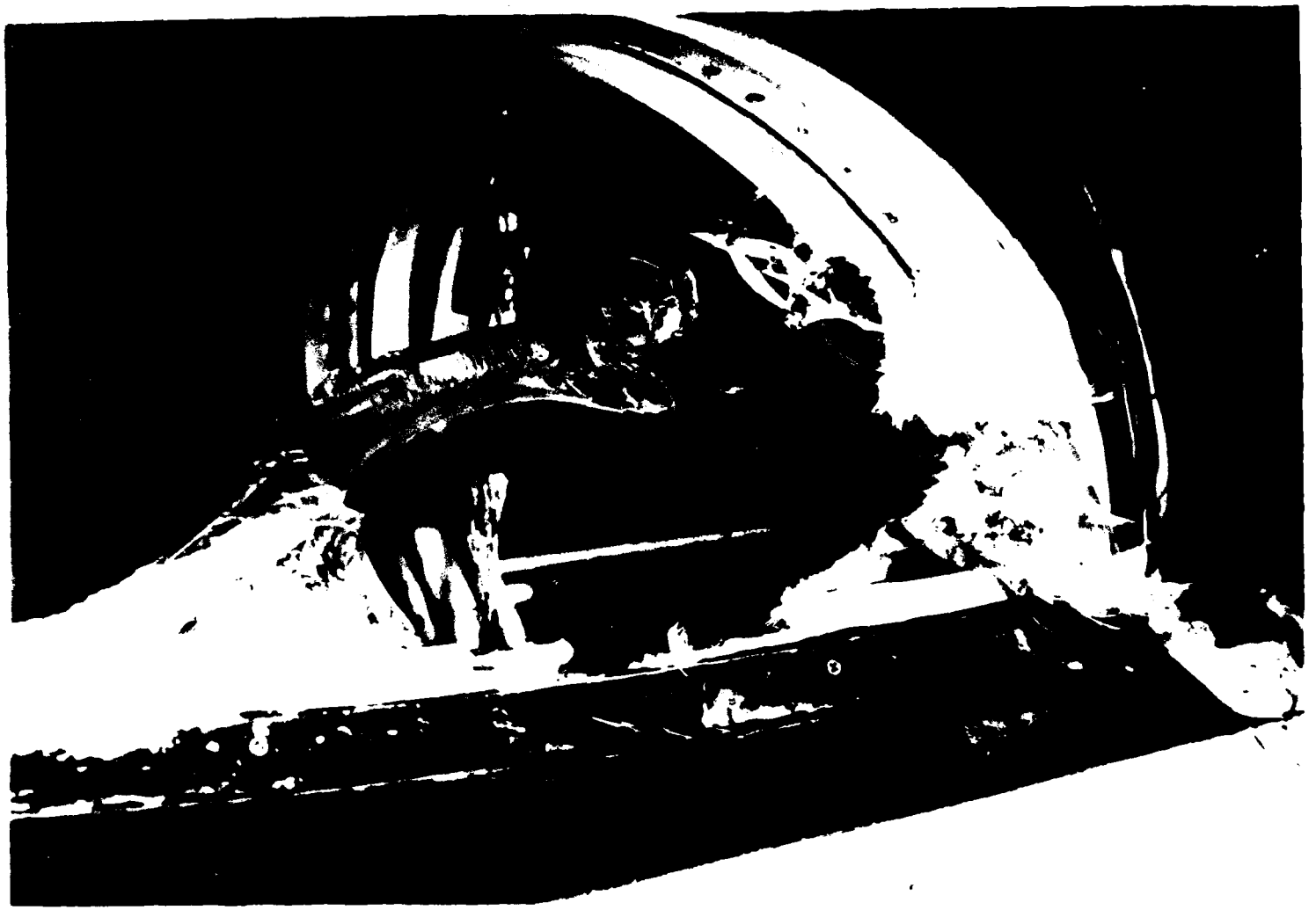


Figure B-16. T-38 Forward Windshield After Test No. 646.

Figure B-17. Close-Up View of T-38 Forward Windshield After Test No. 646.

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